Analysis of Historical Gross Gamma Logging Data from BY Tank Farm

D. A. Myers
Waste Management Northwest/Three Rivers Scientific
Richland, WA 99352
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Abstract: Gross gamma ray logs, recorded from January 1975 through mid-year 1994 as part of the Single-Shell Tank Farm Dry Well Surveillance Program, have been reanalyzed for the BY tank farm to locate the presence of mobile radionuclides in the subsurface. This report presents the BY tank farm gross gamma ray data in such a way as to assist others in their study of vadose zone mechanisms.

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Summary of Data Analysis Results for the BY Single Shell Tank Farm Dry Well Gross Gamma Ray Surveillance Logs

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Glenda K. Jaeger
Benton City, Washington 99320

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1.0 Introduction

The single-shell tank farm dry well surveillance program was established 1947 as one of several methods used to identify leaking tanks and operated until 1994. Up until 1975, data were collected in a non-digital format and in 1975, the surveillance program was upgraded to a digital logging system. Under the new system, gross gamma ray logs were recorded in digital form utilizing several logging detector types and reviewed in order to identify leaks of radioactive liquid from the underground tanks. Gross gamma ray logs recorded from January 1975 through mid-year 1994 have been re-analyzed to locate the presence of mobile radionuclides in the subsurface not targeted under the original program (data acquired prior to 1975 are not in the correct format for this analysis). Details concerning how this was accomplished are in "Analysis Techniques Applied to the Dry Well Surveillance Gross Gamma Ray Data at the SX Tank Farm," WMNW-TRS-ES-VZMA-001.

A necessary element for the analysis of the gross gamma ray data is the use of information provided from the spectral gamma logging analysis implemented from 1996 to 1997. The analysis was performed on BY Tank Farm wells by MACTEC-ERS of Grand Junction, Colorado for the U.S. Department of Energy (DOE) under contract #DE-AC04-94AL96907 (MACTEC-ERS, 1997). The spectral gamma logging system (SGLS) employs a high-purity germanium (HPGe) detector to obtain data leading to the identification and depth of gamma ray emitting radioactive isotopes. Knowledge as to the isotopes that are present in the subsurface is required to adequately interpret the tank farm dry well surveillance logs. By integrating SGLS data with historical dry well surveillance data, knowledge is gained concerning the behavior of radionuclides in the vadose zone over time.

A goal of this report is to present the BY Tank Farm gross gamma ray data in such a way as to assist others in their study of vadose zone mechanisms, allowing them to further analyze the data and develop their own conclusions and interpretations. Overall trends in the data, as well as areas where additional information would be helpful in evaluating the unusual nature of some of the data, will be discussed. It is planned that this presentation will support Tank Waste Remediation System (TWRS) activities for closure, characterization, remediation, and other vadose zone issues. In general, the data analysis resulted in the identification of five types of subsurface conditions that occur within discrete depth intervals called zones. They are defined as follows:

- CLEAN: no systematic trend above the detection threshold for the gross gamma ray logs is indicated by the data.
- STABLE: the decay rate of the isotope(s) identified in the zone matches the change in concentration of the isotope(s) as measured over time, and no noticeable deviation from the match is apparent within the timeframe that gross gamma ray data were collected. Contaminants may be moving, but at a slow enough rate as to not be observable within the timeframe of data collection.
- UNSTABLE/UNSTABLE EARLY: the decay rate of the isotope(s) identified in the zone does not match the change in concentration of the isotope(s) as measured over time within the timeframe that gross gamma ray data were collected. Those zones that exhibit an unstable condition early in this timeframe, but currently exhibit a stable condition, are called unstable or unstable early in this report. Those that are currently unstable are labeled unstable. Currently, isotopes cannot be identified from gross gamma ray data alone. Therefore, isotopes with a rapid rate of decay, such as Ru-106, or at low enough levels to decay below detection limits, may not be identified if the period of instability is prior to the collection of SGLS data. Their presence is speculated based on the fit of the decay curve.
- TANK FARM ACTIVITY: an irregular change in the intensity of gross gamma rays between successive surveys at or near the surface suggests that contamination may be the result of tank farm activities or logging procedure changes and not vadose zone mechanics.
- UNDETERMINED: stability cannot be determined due to insufficient data, exceeding the system design criteria (both upper and lower limits) for recording gross gamma ray data, or possible affects of depth shift or surface activities.

Stable vs. unstable is an apparent condition limited by the time interval over which data were collected, the sensitivity of the tools, and the level of contamination, and is not a definitive statement concerning the fixed or mobile nature of a given isotope.

Note: The category names have changed since the SX report was produced, although the categories are basically the same (i.e., clean, stable, and changed vs. clean, stable, unstable early, and unstable). More kinds of instability were identified in the BY Tank Farm data than in the SX Tank Farm data, which lead to a change in terminology.

It is beyond the scope of this project, to identify the source, rate of movement, or migration pathway of mobile radioactive contaminants and their ultimate impact to the environment. It is also pointed out that where boreholes do not exist, movement can occur without detection. This investigation is limited to the immediate area (approximately 20 inches) around each borehole from which gamma rays are readily detected, and is not rigorous enough to interpret the condition of the space between boreholes and outside of the investigated area.

1.1 Background:

A series of twelve tanks were installed at the BY Tank Farm from 1946 to 1947 to receive liquid waste resulting from activities at the Hanford site (Brevick, et. al.). These tanks are 75 feet in diameter, constructed on 100-foot centers, with 25 feet between the sides of each tank, and are interconnected in a variety of ways. A network of vadose monitoring wells (dry wells) was installed throughout the BY Tank Farm over a number of years to monitor the subsurface condition of the tank farm (Figure 1). All of the 70 wells constructed have a single string of casing installed concurrent to the drilling activity to prevent collapse of the unconsolidated subsurface sediments (loose sand and gravel). An additional borehole (22-00-05) was drilled south of the 104 and 101 tanks for which there are no geophysical data available. The boreholes range in depth from 85 to 150 feet, with the majority being 100 feet deep. The gross gamma ray data that were acquired digitally from these wells between 1975 and 1994 were analyzed by Three Rivers Scientific and presented in "Analysis of Historical Gross Gamma Logging Data from BY Tank Farm," (Project No. 772028, Task No. 23020001).

1.2 Data Analysis Description:

Data from the dry well logs are compiled through a number of iterations until data sets are obtained that reveal any trend present. This process does not add or delete data, but merely compiles them into a useful, uncompromised data set. A depth vs. time plot, or stack plot, of the gross gamma ray data is created to identify trends and zones of contamination. All historical log surveys for one dry well (borehole) are analyzed as a whole for each radioactive zone in a well, thus allowing statements to be made about the apparent condition or rate of change of any given radioactive interval.

Review of the historical gross gamma ray data revealed that limits in the system design for collecting data prior to 1983 created a situation where the zero point for the start of data collecting was inconsistent (refer to WMNW-TRS-ES-VZMA-001 for details). This makes evaluating trends in the data difficult. Several methods can be employed to overcome varying zero points and to essentially create a common starting point from which to view the data, making trend identification easier. These methods apply a depth shift to the data, which is simply adjusting data up or down so that certain identifiable features in the data can be aligned and evaluated. By applying a depth shift to the data, the ability to identify downward movement of the isotopes can be hindered, so depth shifting is avoided as much as possible.

A summation of the values of logging instrument readings over the depth interval of interest minus background activity and times the distance between sample point depths yields a constant that is independent of the specific starting point. This calculation is called the grade thickness product (GTP) and can be applied over a depth interval wide enough to include all variances in depth so as not to require depth shifting. When the calculation is applied over the entire interval, the result is a more accurate representation of the condition of the zone over time.

Gross gamma ray log surveys contain data at one-foot intervals over the length of the borehole. Differences in the zero-depth reference point cause variations in the maximum count rate for thin radioactive zones as well as the apparent depth of contamination. The GTP technique is used to eliminate this variable sampling effect upon the overall net change for a given zone.

Applying a GTP calculation over an entire interval can mask the presence of discrete stable or unstable zones within the interval. Therefore, smaller intervals are evaluated to obtain a clearer understanding of the movement of isotopes in the overall contaminated zone. Occasionally, the smaller intervals overlap in order to aid in the interpretation of trends in the overall zone of interest and to account for depth errors. For clarity of presentation in this summary report, the analysis for the entire interval is presented with a discussion of discrete zones included where appropriate. For detailed information about the analysis and the zones investigated, see the aforementioned BY Tank Farm analysis report. At very low levels of contamination, inconsistencies were observed between the gross gamma indications and the SGLS data. Also, inconsistencies in the data analysis (e.g., depth intervals analyzed, isotopes used in calculating decay curves [sometimes known, sometimes hypothesized]), interpretation of the data, incompleteness in reporting of the evaluation, and errors in the BY Tank Farm analysis report make summarizing difficult. These inconsistencies are driven in part by the complexity of the contaminate movement, and information gathered from the logging process. It is recommended that the BY Tank Farm analysis report and its authors be consulted when applying the information presented in this summary report.

Note: Gross gamma ray data were collected using a variety of probe types. The values generated by these probe types do not correlate with each other (e.g., the NaI probe type 04 does not record values that relate to those recorded with the Green or Red GM probe types 01 and 02). It is not within the scope of this project to normalize these values. Therefore, caution must be used when relating GTP values in zones recorded with different probe types. See WMNW-TRS-ES-VZMA-001 for a detailed discussion.

The average background activity of naturally occurring potassium, uranium, and thorium is obtained from review of the data for each survey and provides a level of confidence that the instrumentation worked consistently and the gross gamma ray data are valid. The percentage of data values that are considered as representing a natural background formation response (frequency clean) is also calculated. The average background activity value is calculated for all survey depth samples between a lower and upper count rate threshold. The lower count rate threshold is generally set at zero (0) c/s; a value defined as indicating a data gap. The upper count rate threshold is generally set at 50 c/s for probe type 04 (NaI), a conservative value near what is considered background activity, yet one fourth of the count rate considered reportable by the leak detection program.

Note: Spurious data are generated during normal data collecting activities. Spurious zero values are called data gaps and are considered as unrealistically low natural background activity when recorded with the sodium-iodide probes. Between 1975 and 1982, the equipment would occasionally record a spurious data value of minus one (-1) or zero (0). A value of minus one represents an invalid count rate. Data gaps occur at various locations in the surveys, including in the background or in the middle of a high contamination zone within a borehole. Data gaps are not included in the calculation of average background, grade thickness product, or frequency clean values.

Zones where contamination is identified are examined using the GTP evaluation. The average background activity is subtracted so that only the contaminated levels above background are included in the analysis. The GTP is plotted in a graph against time for each depth interval analyzed. One or more decay lines are then overlaid on the graph based on isotopes identified by the SGLS data, knowledge of tank constituents, and the known presence of isotopes in other boreholes. Sometimes decay lines can be fit through the data in a number of ways with none of them fitting perfectly. When two or more isotopes are identified, a least squares fit analysis for a multi-component decay is performed (for details, refer to the Appendix in the BX Tank Farm report) for those isotopes that are needed to make the decay curve fit the data. If an isotope was identified (usually at low levels) but is not useful in fitting the curve, it was not included in the GTP calculation. Isotopes that are known to exist in the inventory of the tank farm, or are identified in nearby wells, may not be identified by the SGLS due to being at or below detection levels. Such isotopes are hypothesized to have been present and are sometimes included in the least squares fit analysis when needed to make a fit. The decay rates for each of the components are held fixed in the fitting process and only the relative intensities of the components are calculated. The relative contribution of gross gamma rays from one component to another depends upon the nature of the isotopes and the detector design. Comparing the GTP data and the decay line(s) reveals information about the rate of change of contamination within a zone over the timeframe that data were collected. Multiple plots are generated to show the results for different zones within a borehole when appropriate. The details for the use of GTP are covered in WMNW-TRS-ES-VZMA-001.

The objective of the analysis is to assure that a thorough examination of dry well surveillance logs is performed. It is also to assure that no zones of contamination abruptly entered the borehole survey region and quickly migrated out. All surveys are examined so that no unusual problems or conditions remain as undetected. Table 1 contains a list of the wells located in the BY Tank Farm as well as information concerning the identity, level, and depth of contamination. Due to the complex nature of the data, detailed comments from the summaries in the BY data set are also provided to aid in understanding. In order to afford a spatial relationship to the subsurface contamination, a variety of maps depicting tank and data point locations are provided.

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Table 1. BY Zones

Borehole Number	Total Depth feet	Number of Surveys	[a]Probe Type	Subsurface Condition Category	Zone Depth feet	Max. GTP ft*c/s	Year Max. GTP	Isotopes Identified	Comment
22-00-01	140	340	4	[b]Stable	40-65	250	1975	^{137}Cs	No SGLS data; ^{137}Cs not identified
				Stable	70-84	70	1975	^{137}Cs	
				Stable	84-100	70	1975	^{137}Cs	
22-00-02	100	206	4	Stable	0-14	600	1975	^{137}Cs	Borderline downward movement
				[c]Undetermined	45-56	1,300	1975	^{60}Co; ^{125}Sb	Possible downward movement, but below detection
				Stable	56-64	1,200	1975	^{125}Sb; *^{106}Ru	
				[d]Unstable	64-96	1,800	1975	^{60}Co	Downward movement at low levels; ^{137}Cs decay curve fits, but was not used as ^{137}Cs was not identified by the SGLS
22-00-03	145	208	4	Stable	40-80	3,000	1975	^{60}Co; ^{125}Sb	
				Unstable early	80-117	12,000	1975	^{60}Co	
				Stable	117-128	1,800	1975	^{60}Co	
				Stable	128-140	1,100	1975	^{60}Co; *^{125}Sb	
22-00-04	100	210	4	[e]TF Activity	0-10	200	1975	^{137}Cs	
				Stable	48-70	500	1975	^{60}Co; *^{125}Sb	
				Stable	70-85	1,000	1975	^{60}Co; *^{106}Ru	
22-00-05		no data							No geophysical data available
22-00-10	120	385	4	TF Activity	0-10	150	1975	^{137}Cs	^{137}Cs id'd at 8 pCi/g should appear in gross gamma log at 46 feet, but doesn't
22-01-01	100	405	4	TF Activity	0-6	400	1985	^{137}Cs	
				[f]Appear stable	6-15	50	1975	^{137}Cs	Low levels near threshold
22-01-03	100	395	4	TF Activity	0-10	100	1975	^{137}Cs	
22-01-04	100	408	4	TF Activity	0-15	1,700	1975	^{137}Cs	
				Stable	15-30	16,000	1975	^{137}Cs	
				Stable	30-60	1,400	1975	^{60}Co; *^{125}Sb	
22-01-07	100	394	4	TF Activity	0-6	6,000	1975	^{137}Cs	
				Stable	6-15	100	1975	^{137}Cs	Low levels near threshold
				Stable	40-55	200	1975	^{60}Co	
22-01-10	100	419	4	TF Activity	0-10	1,500	1975	^{137}Cs	
				Stable	15-25	500	1975	^{137}Cs	
				Stable	25-44	550	1975	^{137}Cs; *^{60}Co	
22-02-01	100	593	4	TF Activity	0-10	800	1985	^{137}Cs	
				TF Activity	10-20	200	1984	^{137}Cs	

				Stable	40-53	3,200	1975	^{137}Cs	
				Stable	55-75	200	1975	^{*106}Ru	
				Stable	80-96	550	1975	^{60}Co; ^{*106}Ru	
22-02-02	100	540	4	TF Activity	0-6	600	1975	^{137}Cs	
				Stable	6-18	300	1975	^{137}Cs	
22-02-05	100	545	4	TF Activity	0-10	300	1975	^{137}Cs	
22-02-07	150	452	4	TF Activity	0-10	200	1986	^{137}Cs	No SGLS due to high surface rad. area for personnel
22-02-09	100	607	4	TF Activity	0-10	400	1986	^{137}Cs	
				Stable	20-26	200	1975	^{*125}Sb	
				Stable	26-34	450	1975	^{*125}Sb; ^{*106}Ru	
				Stable	34-44	1,800	1975	^{*125}Sb; ^{*106}Ru	
				Stable	44-52	2,500	1975	^{137}Cs; ^{60}Co; ^{*106}Ru	
				Undetermined	55-65	100	1975	^{60}Co	Low levels near threshold
22-03-01	95	538	4	TF Activity	0-10	200	1986	^{137}Cs	
22-03-04	100	457	4	TF Activity	0-10	900	1975	^{137}Cs	
				TF Activity	10-30	800	1975	^{137}Cs	
				Stable	40-55	2,800	1975	^{125}Sb	
				Stable	55-85	900	1975	^{60}Co; ^{*125}Sb	
22-03-05	100	235	1	Undetermined	0-5	300	1984	^{137}Cs	Lack of depth control
				Stable	5-15	350	1980	^{137}Cs	
				Stable	15-60	170,000	1980	^{137}Cs	Count rate limits exceeded
				Stable	60-85	1,700	1980	^{137}Cs	
22-03-06	100	490	4	TF Activity	0-10	900	1975	^{137}Cs	
				Appear stable	20-28	2,300	1975	^{137}Cs	
				Stable	37-48	13,000	1975	^{137}Cs; ^{60}Co; ^{125}Sb	
				Stable	48-60	2,400	1975	^{*125}Sb; ^{*106}Ru	
				Stable	60-94	4,300	1975	^{60}Co; ^{*125}Sb; ^{*106}Ru	
				Stable	94-100	1,000	1975	^{*125}Sb	Interval not logged after mid 1982
22-03-07	100	475	4	TF Activity	0-8	100	1975	^{137}Cs	
				Stable	47-62	1,300	1975	^{60}Co; ^{*125}Sb	
				Stable	62-90	1,100	1975	^{60}Co; ^{*106}Ru	
22-03-08	100	504	4	TF Activity	0-8	200	1975	^{137}Cs	
				Stable	40-60	1,300	1975	^{60}Co; ^{*106}Ru	
				Appear stable	80-98	100	1975	^{60}Co	Low levels near threshold
°22-03-09	100	618	4	TF Activity	0-11	2,000	1975	^{137}Cs; ^{154}Eu	

				Undetermined	11-24	2,600	1975	^{*106}Ru	^{106}Ru decay rate does not match exactly
				Unstable early	24-52	29,000	1976	^{60}Co; ^{*125}Sb; ^{*106}Ru	
				Unstable	48-95	16,000	1976	^{60}Co; ^{*125}Sb	Downward movement to below well in 1993
22-03-10	100-85	472	4	TF Activity	0-8	300	1975	^{137}Cs	Borehole filled in to 85 feet in 1980
				Stable	8-30	170	1975	^{137}Cs	Low levels near threshold
22-04-01	100	439	4	Appear stable	20-35	250	1975	^{*106}Ru	
				Stable	35-45	150	1975	^{*106}Ru	
22-04-05	100	403	4	[b]Clean					
22-04-07	100	409	4	Clean					
22-04-09	100-125	451	4	TF Activity	0-8	200	1984	^{137}Cs	
				Unstable early	75-95	1,800	1980	^{60}Co	
				Stable	105-120	500	1984	^{60}Co	Well deepened in 1983 and condition is stable
22-04-11	100	405	4	TF Activity	0-8	200	1984	^{137}Cs	
				Stable	10-25	200	1975	^{137}Cs	
				Stable	25-50	1,500	1975	^{*106}Ru	
				Undetermined	90-100	1,000	1975	^{60}Co	
22-05-01	100	737	4	TF Activity	0-10	130,000	1985	^{137}Cs	Some surveys are near count rate limits
22-05-05	100	704	4	TF Activity	0-10	120	1975	^{137}Cs	
22-05-09	100	643	4	Unstable early; undetermined late	55-90	1,000	1975	^{60}Co	Downward movement
22-06-01	100	726	4	TF Activity	0-8	400	1984	^{137}Cs	
				Stable	42-52	200	1975	^{*125}Sb	
				Stable	52-65	600	1975	^{60}Co; ^{*106}Ru	
22-06-05	100	718	4	TF Activity	0-8	70	1975	^{137}Cs	
				Appear stable	28-36	500	1975	^{60}Co; ^{*125}Sb	
				Unstable	40-84	10,000	1975	^{60}Co; ^{*125}Sb	Downward movement
22-06-07	140	535	4	TF Activity	0-8	200	1984	^{137}Cs	
				Unstable early	40-52	300	1975	^{137}Cs	
				Unstable early	52-80	1,100	1979	^{60}Co	Downward and lateral movement
22-06-09	100	709	4	Unstable early	70-90	650	1975	^{*106}Ru	
22-06-11	100	543	4	TF Activity	0-10	200	1975	^{137}Cs	
22-07-01	100	242	4	TF Activity	0-10	300	1975	^{137}Cs	
				Unstable early	40-52	800	1976	^{137}Cs	
				Stable	52-70	3,500	1975	^{60}Co	
				Stable	70-92	3,000	1975	^{60}Co	

22-07-02	100	336	4	Appear stable	6-20	200	1975	^{137}Cs	
				Unstable early	42-95	2,800	1976	^{60}Co	Downward movement; contamination may be below bottom of well
22-07-05	100	238	4	Unstable early	40-78	3,800	1975	^{60}Co	Downward movement within the zone from 42 to 65 feet
				Undetermined	90-100	500	1975	^{137}Cs	
22-07-07	100	225	4	Unstable early	30-54	2,500	1975	^{137}Cs; *^{125}Sb; *^{106}Ru	
				Unstable	80-98	1,800	1976	^{60}Co; ^{125}Sb	Stable from 1983 or 1990
22-07-09	100	393	4	TF Activity	0-9	2,500	1984	^{137}Cs	
				Stable	9-17	1,400	1975	^{137}Cs	
				Appear stable	17-36	50,000	1975	^{137}Cs	Count rate may have been exceeded
				Unstable	62-100	2,200	1976	^{137}Cs; ^{60}Co	Downward movement to below well bottom in 1990
22-07-10	97	356	4	TF Activity	0-6	1,500	1975	^{137}Cs	
				Stable	6-12	2,000	1975	^{137}Cs	
				Stable	12-20	1,400	1975	^{137}Cs	
				Stable	20-30	1,600	1975	^{137}Cs	
				Stable	30-44	1,400	1975	^{137}Cs	
22-08-01	100	312	4	TF Activity	0-12	200,000	1989	^{137}Cs	Count rate may have been exceeded
				Stable	22-32	500	1976	^{60}Co; *^{125}Sb	
				Stable	32-42	2,400	1976	^{60}Co; *^{125}Sb	
				Stable	42-59	25,000	1975	^{60}Co; *^{125}Sb	
				Unstable	59-95	12,000	1975	^{60}Co; *^{125}Sb	Movement of isotopes is unclear; stable from 1985 to 1994
22-08-02	100	305	4	TF Activity	0-10	20,000	1993	^{137}Cs	
				Stable	20-30	1,000	1975	*^{125}Sb	
				Unstable	44-100	15,000	1975	^{60}Co; *^{125}Sb	Downward movement, possibly below bottom of borehole
22-08-05	100	314	4	TF Activity	0-8	200	1975	^{137}Cs	
				Stable	36-45	250	1975	^{60}Co	
				Stable	45-53	700	1975	^{60}Co	
				Stable	53-63	1,000	1975	^{60}Co	
				Unstable early	63-84	900	1975	^{60}Co	Downward movement
22-08-06	100	314	4	TF Activity	0-8	1,200	1975	^{137}Cs	
				TF Activity	8-18	500	1975	^{137}Cs	
				Stable	18-29	400	1975	^{137}Cs	
				Stable	46-54	150	1975	^{137}Cs; ^{60}Co	
				Stable	54-63	200	1975	^{60}Co	
				Stable	63-73	900	1975	^{60}Co	
				Unstable early	73-83	450	1975	^{60}Co	

22-08-07	135	296	4	TF Activity	0-8	500	1975	^{137}Cs	
22-08-09	100	403	4	TF Activity	0-10	80,000	1984	^{137}Cs	
				Unstable early	72-84	150	1975	^{137}Cs; $^{*106}Ru$	
22-08-12	105	380	4	TF Activity	0-8	10,000	1989	^{137}Cs	
				Unstable early	25-40	300	1980	^{137}Cs	^{137}Cs decay curve does not fit GTP plot
				Unstable early	40-51	3,000	1975	^{60}Co; $^{*125}Sb$	
				Unstable early	51-60	3,000	1975	^{60}Co	Possible downward movement
				Unstable early	60-82	1,000	1976	^{60}Co	Downward movement within the zone
22-09-01	100	674	4	Stable	24-35	250	1975	$^{*106}Ru$	
				Stable	40-55	2,200	1975	$^{*125}Sb$; $^{*106}Ru$	
22-09-02	100	468	4	TF Activity	0-10	2,000	1984	^{137}Cs	
				TF Activity	10-14	300	1975	^{137}Cs	
				Stable	14-34	1,200	1975	^{137}Cs	
				Stable	42-64	500	1975	$^{*106}Ru$	
22-09-05	100	562	4	TF Activity	0-10	100	1975	^{137}Cs	
				Stable	40-58	250	1975	^{137}Cs; $^{*125}Sb$	
22-09-07	97	481	4	Unstable early	20-40	12,000	1975	$^{*106}Ru$	
				Unstable early	40-50	9,000	1976	$^{*106}Ru$	
				Unstable early	50-64	2,700	1976	$^{*125}Sb$; $^{*106}Ru$	
22-09-08	98	368	4	Undetermined	16-30	80,000	1985	^{137}Cs	Count rate limits exceeded
				Stable	43-52	150	1981	^{60}Co	
				Undetermined	76-90	100	1985	^{60}Co	Levels below detection threshold
22-09-11	100	552	4	TF Activity	0-10	1,500	1975	^{137}Cs	
				Stable	16-25	300	1975	^{137}Cs; $^{*125}Sb$	
				Stable	25-38	450	1975	$^{*106}Ru$	
				Unstable early	38-52	3,500	1975	$^{*106}Ru$	
22-10-05	100	400	4	Stable	45-55	200	1975	^{60}Co	
				Unstable early	55-75	300	1979	^{60}Co	
22-10-07	100	377	4	Unstable early	45-65	200	1983	^{60}Co	
22-10-09	100	364	4	TF Activity	0-10	20,000	1975	^{137}Cs	
22-10-10	100	406	4	Unstable early	58-76	1,500	1975	^{60}Co	
22-11-01	100	415	4	TF Activity	0-5	1,000	1975	^{137}Cs	
				TF Activity	5-10	900	1975	^{137}Cs	
				Unstable	19-28	4,000	1984	^{137}Cs	
22-11-05	100	450	4	TF Activity	0-10	3,000	1975	^{137}Cs	

22-11-08	100	438	4	TF Activity	0-10	100	1975	^{137}Cs	
				Stable	56-66	120	1975	^{60}Co; $^{235/8}$U	
22-11-09	100	437	4	TF Activity	0-8	8,000	1975	^{137}Cs	
				Stable	24-34	450	1975	^{60}Co	
				Unstable early	34-46	250	1975	^{60}Co	
22-12-01	100	424	4	Clean					
22-12-03	100	509	4	TF Activity	0-10	200,000	1980	^{137}Cs	Count rate limits exceeded
				Stable	10-20	300	1975	^{137}Cs	
22-12-05	100	426	4	TF Activity	0-20	1,000	1975	^{137}Cs	
22-12-06	100	428	4	TF Activity	0-20	8,000	1975	^{137}Cs	
22-12-07	100	418	4	TF Activity	0-10	1,500	1984	^{137}Cs	
22-12-09	100	429	4	Clean					
22-12-10	100	424	4	Clean					

[a]Probe type: 1 = Green GM, moderately sensitive; reads moderate levels of gamma ray activity.
4 = NaI, most sensitive, reads lowest level of gamma ray activity.
Caution must be used when relating GTP values in zones recorded with different probe types.

[b]The decay rate of the isotope(s) identified in the zone matches the change in concentration of the isotope(s) as measured over time, and no noticeable deviation from the match is apparent within the timeframe that gross gamma ray data were collected.

[c]Stability cannot be determined due to insufficient data, exceeding the system design criteria (both upper and lower limits) for recording gross gamma ray data, or possible affects of depth shift or surface activities.

[d]The decay rate of the isotope(s) identified in the zone does not match the change in concentration of the isotope(s) as measured over time within the timeframe that gross gamma ray data were collected. Those zones that exhibit an unstable condition early in this timeframe, but currently exhibit a stable condition, are called unstable or unstable early in this report.

[e]An irregular change in the intensity of gross gamma rays between successive surveys at or near the surface suggests that contamination may be the result of tank farm activities or logging procedure changes and not vadose zone mechanics.

[f]The decay rate of the isotope(s) identified in the zone appears to match the change in concentration of the isotope(s) as measured over time, but stability cannot be rigorously determined.

[g]Well 22-03-09 exhibits downward movement with lateral influx from 1975 to 1977 and downward movement from 1977 to 1995 (it is not possible to tell if there is lateral movement during this time period); stringers of contamination are left behind after the majority of the contamination moves through; the leading edge of the contamination moves below the bottom of the borehole in 1985 to 1986 and continues to move down until the trailing edge of the contamination moves below the bottom of the borehole in 1991 to 1992.

[h]No systematic trend above the detection threshold for the gross gamma ray logs is indicated by the data.

[i]Currently, isotopes cannot be identified from gross gamma ray data alone; therefore, isotopes with a rapid rate of decay, such as Ru-106, may not be identified if the period of instability is prior to the collection of SGLS data. Also, isotopes that are at low enough levels to decay below detection limits when SGLS data were collected may not be identified.

Stable vs. unstable is an apparent condition limited by the time interval over which data were collected and the level of contamination, and is not a statement concerning the fixed or mobile nature of a given isotope.

Certain limitations in the data available for analysis make evaluation less complete. Some of the limitations are as follows:

- Inability to identify when down-hole contamination is a result of vadose zone mechanics or drag down during well installation
- Insufficient gross gamma ray data to establish a statistical trend or rigorous statistical analysis
- Incomplete timeframe over which data are available
- Lack of data below well bottom
- Inability to identify isotopes that have decayed to levels below the detection limits of the SGLS.

2.0 Subsurface Condition Categories

2.1. Clean:

A clean well is one that exhibits no observable change in the character of the activity over the logging history of the well, and does not have any statistically significant levels above natural background over the timeframe of gross gamma ray data collection. Although spurious surveys (those readings that do not repeat over time) may exist in the frequency clean and the average background plots, the trend of the data is clear. Five out of 70 wells in the BY Tank Farm are considered clean (Figure 2) and are listed in Table 2. The remaining 65 wells are considered contaminated and are further categorized and discussed in the following sections.

Table 2. Clean Zones

Borehole Number	Total Depth feet	Subsurface Condition Category
22-04-05	100	Clean
22-04-07	100	Clean
22-12-01	100	Clean
22-12-09	100	Clean
22-12-10	100	Clean

2.2. Contaminated:

Identification of specific gamma emitting isotopes that are in the subsurface is attainable from data acquired by the SGLS. Integration of the decay rate of the radionuclide species with the gross gamma ray data collected during the dry well surveillance program provides insight as to the rate of change, if any, of radionuclides in the subsurface. During the analysis of BY Tank Farm data, seven isotopes were identified through SGLS analysis or hypothesized to occur in radioactive zones. They are cesium-137 (Cs-137), cobalt-60 (Co-60), antimony-125 (Sb-125), uranium-235 and -238 (U-235/8), europium-154 (Eu-154), and ruthenium-106 (Ru-106).

The most commonly found isotope is Cs-137, which is primarily found by itself throughout the tank farm from surface to 20 feet. It is found with various combinations of the other isotopes from 20 to 100 feet. Cobalt-60 is found from 22 to 140 feet and occurs primarily to the northwest and southeast of the 103 tank, spread between the 107 and 109 tanks, to the west of the 110 and 111 tanks, and to the south of the 107 and 110 tanks. It is found deeper than 100 feet in only two wells: 22-00-03 and 22-04-09. Antimony-125 is found from 16 to 140 feet and is fairly localized around the 109 tank, to the northeast side of the 108 tank, to the southeast of the 103 tank, with a few occurrences elsewhere in the tank farm. It is often hypothesized to have been present as levels of Sb-125 fell below the detection threshold by the time of the SGLS analysis. It is hypothesized to be deeper than 100 feet only in well 22-00-03. In a few instances, Sb-125 was not identified by the SGLS, yet the levels of radioactivity in 4 zones in 4 wells prior to the SGLS analysis suggest that there was sufficient Sb-125 present to have been identified by SGLS given stable conditions. These zones are: 48 to 70 feet in well 22-00-04, 34 to 44 feet in well 22-02-09, 42 to 59 feet in well 22-08-01, and 40 to 51 feet in well 22-08-12. Review of the raw SGLS data gathered from these intervals might provide supporting documentation for the hypothesized presence of Sb-125. Ruthenium-106 is hypothesized to have been present from 11 to 96 feet in the north part of the tank farm around the 109, 106, and 103 tanks and to the south part of the tank farm, primarily around the 104 tank. Uranium-235/8 is identified in only one well, 22-11-08 from 56 to 66 feet. Europium-154 is identified in only one well, 22-03-09 from 0 to 11 feet.

Ruthenium-106 is not currently present above the detection threshold in any of the wells examined by the SGLS. This is due to the very rapid exponential decline over a short half-life of 1.02 years. Ruthenium-106 is hypothesized to have been present in 17 wells in 1975 and in one well in 1976 on the basis of the gross gamma ray data, the resulting GTP calculations that mimic the decay rate of Ru-106, and the inventory list of known radionuclides for that time period. It must be noted, however, that the method of fitting a decay curve to the observed GTP trend identifies only those contaminants that are not changing. Therefore, it is assumed that Ru-106 is present if the decay curve for Ru-106 matches the GTP plot. If any decay curve does not match, then the contaminants cannot be identified with this method without additional information. The isotopes identified with the SGLS are primarily found to be present under four subsurface conditions: stable, unstable/unstable early, tank farm activity, and undetermined. The location of wells labeled with the conditions of subsurface zones is shown in Figure 2. A different condition can be indicated for each zone within a well with multiple zones.

2.2.1 <u>Tank Farm Activity:</u>

An irregular change in the intensity of gross gamma rays between successive surveys at or near the surface suggest that contamination may be the result of tank farm activities or logging procedure changes and not vadose zone mechanics. Cs-137 exists near the surface in 47 wells, affecting as much as 30 feet below surface, apparently as the result of tank farm activities (i.e., logging procedure changes, transfer line operations, valve box and conduit leaks, spills, etc.). The wells affected by tank farm activities are listed in Table 3. Thirty three of these wells are or appear to be stable from 1986 to the end of gross gamma ray data collection and are labeled as such in the table. Thirty-five wells have additional radioactive zones at depth that are categorized according to the rate of change, if any, exhibited by the radionuclides present and are included in the discussions that follow.

Table 3. BY Tank Farm Activity Zones

Borehole Number	Total Depth feet	Subsurface Condition Category	Zone Depth feet	Max. GTP ft*c/s	Year Max. GTP	Isotopes Identified	Comment
22-00-04	100	TF Activity	0-10	200	1975	^{137}Cs	
22-00-10	120	TF Activity	0-10	150	1975	^{137}Cs	
22-01-01	100	TF Activity	0-6	400	1985	^{137}Cs	
22-01-03	100	TF Activity	0-10	100	1975	^{137}Cs	
22-01-04	100	TF Activity	0-15	1,700	1975	^{137}Cs	
22-01-07	100	TF Activity	0-6	6,000	1975	^{137}Cs	
22-01-10	100	TF Activity	0-10	1,500	1975	^{137}Cs	
22-02-01	100	TF Activity	0-10	800	1985	^{137}Cs	
		TF Activity	10-20	200	1984	^{137}Cs	
22-02-02	100	TF Activity	0-6	600	1975	^{137}Cs	
22-02-05	100	TF Activity	0-10	300	1975	^{137}Cs	
22-02-07	150	TF Activity	0-10	200	1986	^{137}Cs	No SGLS; high surface radiation area
22-02-09	100	TF Activity	0-10	400	1986	^{137}Cs	
22-03-01	95	TF Activity	0-10	200	1986	^{137}Cs	
22-03-04	100	TF Activity	0-10	900	1975	^{137}Cs	
		TF Activity	10-30	800	1975	^{137}Cs	
22-03-06	100	TF Activity	0-10	900	1975	^{137}Cs	
22-03-07	100	TF Activity	0-8	100	1975	^{137}Cs	
22-03-08	100	TF Activity	0-8	200	1975	^{137}Cs	
22-03-09	100	TF Activity	0-11	2,000	1975	^{137}Cs; ^{154}Eu	
22-03-10	100-85	TF Activity	0-8	300	1975	^{137}Cs	Borehole filled in to 85 feet in 1980
22-04-09	100-125	TF Activity	0-8	200	1984	^{137}Cs	
22-04-11	100	TF Activity	0-8	200	1984	^{137}Cs	
22-05-01	100	TF Activity	0-10	130,000	1985	^{137}Cs	Some surveys are near count rate limits

22-05-05	100	*TF Activity	0-10	120	1975	^{137}Cs	
22-06-01	100	*TF Activity	0-8	400	1984	^{137}Cs	Very low levels after 1986
22-06-05	100	TF Activity	0-8	70	1975	^{137}Cs	
22-06-07	140	TF Activity	0-8	200	1984	^{137}Cs	
22-06-11	100	*TF Activity	0-10	200	1975	^{137}Cs	
22-07-01	100	TF Activity	0-10	300	1975	^{137}Cs	
22-07-09	100	*TF Activity	0-9	2,500	1984	^{137}Cs	
22-07-10	97	TF Activity	0-6	1,500	1975	^{137}Cs	
22-08-01	100	*TF Activity	0-12	200,000	1989	^{137}Cs	Count rate may have been exceeded
22-08-02	100	TF Activity	0-10	20,000	1993	^{137}Cs	
22-08-05	100	*TF Activity	0-8	200	1975	^{137}Cs	
22-08-06	100	*TF Activity	0-8	1,200	1975	^{137}Cs	
		*TF Activity	8-18	500	1975	^{137}Cs	
22-08-07	135	*TF Activity	0-8	500	1975	^{137}Cs	
22-08-09	100	*TF Activity	0-10	80,000	1984	^{137}Cs	
22-08-12	105	TF Activity	0-8	10,000	1989	^{137}Cs	
22-09-02	100	*TF Activity	0-10	2,000	1975	^{137}Cs	
		*TF Activity	10-14	300	1975	^{137}Cs	
22-09-05	100	TF Activity	0-10	100	1975	^{137}Cs	
22-09-11	100	*TF Activity	0-10	1,500	1975	^{137}Cs	
22-10-09	100	*TF Activity	0-10	20,000	1975	^{137}Cs	
22-11-01	100	TF Activity	0-5	1,000	1975	^{137}Cs	
		TF Activity	5-10	900	1975	^{137}Cs	
22-11-05	100	TF Activity	0-10	3,000	1975	^{137}Cs	
22-11-08	100	TF Activity	0-10	100	1975	^{137}Cs	
22-11-09	100	*TF Activity	0-8	8,000	1975	^{137}Cs	
22-12-03	100	*TF Activity	0-10	200,000	1980	^{137}Cs	Count rate limits possibly exceeded
22-12-05	100	*TF Activity	0-20	1,000	1975	^{137}Cs	
22-12-06	100	*TF Activity	0-20	8,000	1975	^{137}Cs	
22-12-07	100	TF Activity	0-10	1,500	1984	^{137}Cs	Mostly below detection limit except around 1985

*Stable or appears to be stable after 1986.

2.2.2 Undetermined:

Infrequently, the subsurface condition of a zone with radioactive contamination cannot be determined and the zone is therefore classified as undetermined. There are eight zones in seven wells examined that are undetermined (Table 4). These zones occur throughout the subsurface and have:

- Data that are too near or below the threshold for detection limits, or timeframe of data collection is too short to determine stability due to statistical variations
- Possibly been affected by depth shift or surface activities
- An isotope(s) that is not identified through SGLS analysis, and a decay curve for a hypothesized isotope that does not fit the GTP trend
- Data that were collected with inappropriate equipment.

Table 4. BY Undetermined Zones

Borehole Number	Total Depth feet	Subsurface Condition Category	Zone Depth feet	Max. GTP ft*c/s	Year Max. GTP	Isotopes Identified	Comment
22-00-02	100	Undetermined	45-56	1,300	1975	^{60}Co; ^{125}Sb	Unable to obtain a satisfactory decay curve fit to GTP plot
22-02-09	100	Undetermined	55-65	100	1975	^{60}Co	Low levels near threshold of gross gamma ray detection
22-03-05	100	Undetermined	0-5	300	1984	^{137}Cs	Lack of depth control at surface and short time span of data
22-03-09	100	Undetermined	11-24	2,600	1975	*^{106}Ru	Unable to obtain a satisfactory decay curve fit to GTP plot
22-04-11	100	Undetermined	90-100	1,000	1975	^{60}Co	
22-07-05	100	Undetermined	90-100	500	1975	^{137}Cs	
22-09-08	98	Undetermined	16-30	80,000	1985	^{137}Cs	Count rate limits exceeded
22-09-08		Undetermined	76-90	100	1985	^{60}Co	Levels below detection threshold

*Currently, isotopes cannot be identified from gross gamma ray data alone; therefore, isotopes with a rapid rate of decay, such as Ru-106, or at low enough levels to decay below detection limits, may not be identified if the period of instability is prior to the collection of SGLS data.

2.2.3 Stable:

The subsurface condition of a zone with radioactive contamination is considered stable when:

- The decay rate of the isotope(s) identified with SGLS and/or hypothesized to have been present matches the trend observed in the GTP of the gross gamma ray data
- Contaminants continue to decrease at a rate consistent with the isotope(s) half-life
- No noticeable change in concentration is apparent over the timeframe that data were collected.

Eighty zones are considered stable or apparently stable and are listed in Table 5. Stability is also assumed even if conditions are such that isotopes may be moving at a rate slow enough as to not be observed over the timeframe of gross gamma ray data collection. Currently, there is no way to know the condition prior to or after the data collection period. If a new driver were introduced, such as the influx of a large volume of liquid, contamination could be remobilized. Given the current data, it cannot be determined if remobilization will occur or not, or whether contaminates are currently mobile and changing at levels below detection by the logging system.

Table 5. BY Stable Zones

Borehole Number	Total Depth feet	Subsurface Condition Category	Zone Depth feet	Max. GTP ft*c/s	Year Max. GTP	Isotopes Identified
22-00-01	140	[a]Stable	40-65	250	1975	^{137}Cs
		Stable	70-84	70	1975	^{137}Cs
		Stable	84-100	70	1975	^{137}Cs
22-00-02	100	Stable	0-14	600	1975	^{137}Cs
		Stable	56-64	1,200	1975	Sb^{125}; *^{106}Ru
22-00-03	145	Stable	40-80	3,000	1975	^{60}Co; ^{125}Sb
		Stable	117-128	1,800	1975	^{60}Co
		Stable	128-140	1,100	1975	^{60}Co; *^{125}Sb
22-00-04	100	Stable	48-70	500	1975	^{60}Co; *^{125}Sb
		Stable	70-85	1,000	1975	^{60}Co; *^{106}Ru
22-01-01	100	[b]Appear stable	6-15	50	1975	^{137}Cs
22-01-04	100	Stable	15-30	16,000	1975	^{137}Cs
		Stable	30-60	1,400	1975	^{60}Co; *^{125}Sb
22-01-07	100	Stable	6-15	100	1975	^{137}Cs
		Stable	40-55	100	1975	^{60}Co
22-01-10	100	Stable	15-25	500	1975	^{137}Cs

		Stable	25-44	550	1975	^{137}Cs; ^{*60}Co
22-02-01	100	Stable	40-53	3,200	1975	^{137}Cs
		Stable	55-75	200	1975	^{*106}Ru
		Stable	80-96	550	1975	^{60}Co; ^{*106}Ru
22-02-02	100	Stable	6-18	300	1975	^{137}Cs
22-02-09	100	Stable	20-26	200	1975	^{*125}Sb
		Stable	26-34	450	1975	^{*125}Sb; ^{*106}Ru
		Stable	34-44	1,800	1975	^{*125}Sb; ^{*106}Ru
		Stable	44-52	2,500	1975	^{137}Cs; ^{60}Co; ^{*106}Ru
22-03-04	100	Stable	40-55	2,800	1975	^{125}Sb
		Stable	55-85	900	1975	^{60}Co; ^{*125}Sb
22-03-05	100	Stable	5-15	350	1980	^{137}Cs
		Stable	15-60	170,000	1980	^{137}Cs
		Stable	60-85	1,700	1980	^{137}Cs
22-03-06	100	Appear stable	20-28	2,300	1975	^{137}Cs
		Stable	37-48	13,000	1975	^{137}Cs; ^{60}Co; ^{125}Sb
		Stable	48-60	2,400	1975	^{*125}Sb; ^{*106}Ru
		Stable	60-94	4,300	1975	^{60}Co; ^{*125}Sb; ^{*106}Ru
		Stable	94-100	1,000	1975	^{*125}Sb
22-03-07	100	Stable	47-62	1,300	1975	^{60}Co; ^{*125}Sb
		Stable	62-90	1,100	1975	^{60}Co; ^{*106}Ru
22-03-08	100	Stable	40-60	1,300	1975	^{60}Co; ^{*106}Ru
		Appear stable	80-98	100	1975	^{60}Co
22-03-10	100-85	Stable	8-30	170	1975	^{137}Cs
22-04-01	100	Appear stable	20-35	250	1975	^{*106}Ru
		Stable	35-45	150	1975	^{*106}Ru
22-04-09	100-125	Stable	105-120	500	1984	^{60}Co
22-04-11	100	Stable	10-25	200	1975	^{137}Cs
		Stable	25-50	1,500	1975	^{*106}Ru
22-06-01	100	Stable	42-52	200	1975	^{*125}Sb
		Stable	52-65	600	1975	^{60}Co; ^{*106}Ru
22-06-05	100	Appear stable	28-36	500	1975	^{60}Co; ^{*125}Sb
22-07-01	100	Stable	52-70	3,500	1975	^{60}Co
		Stable	70-92	3,000	1975	^{60}Co
22-07-02	100	Appear stable	6-20	200	1975	^{137}Cs
22-07-09	100	Stable	9-17	1,400	1975	^{137}Cs
		Appear stable	17-36	50,000	1975	^{137}Cs
22-07-10	97	Stable	6-12	2,000	1975	^{137}Cs
		Stable	12-20	1,400	1975	^{137}Cs
		Stable	20-30	1,600	1975	^{137}Cs
		Stable	30-44	1,400	1975	^{137}Cs
22-08-01	100	Stable	22-32	500	1976	^{60}Co; ^{*125}Sb
		Stable	32-42	2,400	1976	^{60}Co; ^{*125}Sb
		Stable	42-59	25,000	1975	^{60}Co; ^{*125}Sb
22-08-02	100	Stable	20-30	1,000	1975	^{*125}Sb
	100	Stable	36-45	250	1975	^{60}Co
		Stable	45-53	700	1975	^{60}Co
		Stable	53-56	1,000	1975	^{60}Co
22-08-06	100	Stable	18-29	400	1975	^{137}Cs

		Stable	46-54	150	1975	^{137}Cs; ^{60}Co
		Stable	54-63	200	1975	^{60}Co
		Stable	63-73	900	1975	^{60}Co
22-09-01	100	Stable	24-35	250	1984	^{*106}Ru
		Stable	40-55	2,200	1975	^{*125}Sb; ^{*106}Ru
22-09-02	100	Stable	14-34	1,200	1975	^{137}Cs
		Stable	42-64	500	1975	^{*106}Ru
22-09-05	100	Stable	40-58	250	1975	^{137}Cs; ^{*125}Sb
22-09-08	98	Stable	43-52	150	1981	^{60}Co
22-09-11	100	Stable	16-25	300	1975	^{137}Cs; ^{*125}Sb
		Stable	25-38	450	1975	^{*106}Ru
22-10-05	100	Stable	45-55	200	1975	^{60}Co
22-11-08	100	Stable	56-66	120	1975	^{60}Co; $^{235/8}$U
22-11-09	100	Stable	24-34	450	1975	^{60}Co
22-12-03	100	Stable	10-20	300	1975	^{137}Cs

[a]The decay rate of the isotope(s) identified in the zone matches the change in concentration of the isotope(s) as measured over time, and no noticeable deviation from the match is apparent within the timeframe that gross gamma ray data were collected.

[b]The decay rate of the isotope(s) identified in the zone appears to match the change in concentration of the isotope(s) as measured over time, but stability cannot be rigorously determined.

[*]Currently, isotopes cannot be identified from gross gamma ray data alone; therefore, isotopes with a rapid rate of decay, such as Ru-106, or at low enough levels to decay below detection limits, may not be identified when SGLS data were obtained.

2.2.4 Unstable:

The condition of a subsurface zone with radioactive contamination is considered unstable when, at some point within the timeframe of data collection, contamination was not decreasing at the decay rate of the isotope(s) identified with SGLS. In this case, the decay curve does not match the trend observed in the GTP of the data. In the BY Tank Farm, 34 zones in 26 wells are identified which exhibit periods of instability early in the timeframe (prior to 1990) that gross gamma ray data were collected. Most of these unstable zones have since developed a consistent rate of decrease through when the last data were collected. Many of the unstable zones have decayed to levels too low to determine stability and are therefore called unstable. Four wells appear to have contamination that has moved below the bottom of the well: 22-03-09, 22-07-02, 22-07-09, and 22-08-02. The estimated rate of movement of the contamination in well 22-03-09 appears to be about 2 feet per year. See Table 6 for list of unstable zones.

Downward movement is seen for the first time in the BY Tank Farm analysis report in 13 wells. Well 22-06-07 also appears to exhibit lateral movement into the zone from 52 to 80 feet. Downward movement is typically identified in the stack plot by an apparent widening of a depth zone of contamination over time. Lateral movement is postulated when the decay curve of isotopes known to be present in the well do not match the GTP plot of the gross gamma ray data and the stack plot does not indicate downward movement. Due to the limited range in distance around the borehole that the logging instruments can record information for, it is not possible to identify if downward movement is restricted to the annulus of the borehole or in the formation adjacent to it. It is also not possible to identify if the contamination is coming from outside of the area of the borehole, or whether it is coming from above or below the contaminated zone within the well area.

Table 6. BY Unstable Zones

Borehole Number	Total Depth feet	Subsurface Condition Category	Zone Depth feet	Max. GTP ft*c/s	Year Max. GTP	Isotopes Identified	Comment
22-00-02	100	Unstable	64-96	1,800	1975	^{60}Co	Downward movement at low levels
22-00-03	145	Unstable early	80-117	12,000	1975	^{60}Co	
22-03-09	100	Unstable early	24-52	29,000	1976	^{60}Co; *^{125}Sb; *^{106}Ru	
		Unstable	48-95	16,000	1976	^{60}Co; *^{125}Sb	Downward movement below bottom of well in 1993. Appears to be moving at an estimated rate of 2 feet per year
22-04-09	100-125	Unstable early	75-95	1,800	1980	^{60}Co	
22-05-09	100	Unstable early; undetermined late	55-90	1,000	1975	^{60}Co	Downward movement
22-06-05	100	Unstable	40-84	10,000	1984	^{60}Co; *^{125}Sb	Downward movement
22-06-07	140	Unstable early	40-52	300	1975	^{137}Cs	
		Unstable early	52-80	1,100	1979	^{60}Co	Downward and lateral movement
22-06-09	100	Unstable early	70-90	650	1975	*^{106}Ru	
22-07-01	100	Unstable early	40-52	800	1976	^{137}Cs	
22-07-02	100	Unstable early	42-95	2,800	1976	^{60}Co	May be downward movement along casing; contaminant may be below bottom of well
22-07-05	100	Unstable early	40-78	3,800	1975	^{60}Co	Downward movement within the zone from 42 to 65 feet
22-07-07	100	Unstable early	30-54	2,500	1975	^{137}Cs; *^{125}Sb; *^{106}Ru	
		Unstable	80-98	1,800	1976	^{60}Co; ^{125}Sb	Stable since 1983 or 1990
22-07-09	100	Unstable	62-100	2,200	1976	^{137}Cs; ^{60}Co	Downward movement to below well bottom in 1990
22-08-01	100	Unstable	59-95	12,000	1975	^{60}Co; *^{125}Sb	Movement of isotopes is unclear; stable from 1985 to 1994
22-08-02	100	Unstable	44-100	15,000	1975	^{60}Co; *^{125}Sb	Downward movement, possibly below bottom of borehole
22-08-05	100	Unstable early	63-84	900	1975	^{60}Co	Downward movement
22-08-06	100	Unstable early	73-83	450	1975	^{60}Co	Levels too low to identify downward movement
22-08-09	100	Unstable early	72-84	150	1975	^{137}Cs; *^{106}Ru	
22-08-12	105	Unstable early	25-40	300	1980	^{137}Cs	^{137}Cs decay curve does not fit GTP plot
		Unstable early	40-51	3,000	1975	^{60}Co; *^{125}Sb	
		Unstable early	51-60	3,000	1975	^{60}Co	Possible downward movement
		Unstable early	60-82	1,000	1976	^{60}Co	Downward movement within the zone
22-09-07	100	Unstable early	20-40	12,000	1975	*^{106}Ru	
		Unstable early	40-50	9,000	1976	*^{106}Ru	
		Unstable early	50-64	2,700	1976	*^{125}Sb; *^{106}Ru	
22-09-11	100	Unstable early	38-52	3,500	1975	*^{106}Ru	
22-10-05	100	Unstable early	55-75	300	1979	^{60}Co	
22-10-07	100	Unstable early	45-65	200	1983	^{60}Co	
22-10-10	100	Unstable early	58-76	1,500	1975	^{60}Co	
22-11-01	100	Unstable	19-28	4,000	1984	^{137}Cs	
22-11-09	100	Unstable early	34-46	250	1975	^{60}Co	

*Currently, isotopes cannot be identified from gross gamma ray data alone; therefore, isotopes with a rapid rate of decay, such as Ru-106, or at low enough levels to decay below detection limits, may not be identified if the period of instability is prior to the collection of SGLS data.

3.0 Details of Contaminated Conditions

3.1 Stable Zones:

Many zones within a number of wells exhibit gross gamma ray activity above natural background. Eighty of these radioactive intervals are observed to be stable as verified by the change in GTP over time coinciding with the decay rate of the isotope(s) identified with SGLS as, or hypothesized to have been present in the well within the timeframe data were collected. The isotopes present in these stable zones vary and are presented in Table 1. In general, they occur as follows:

- Cs-137 occurs as nearly the only man-made isotope present from 0 to 20 feet, and with other isotopes at depth.
- Co-60 occurs as the only man-made isotope present in 46 zones, less commonly with other isotopes.
- Sb-125 is usually present with other isotopes, occasionally by itself.
- Ru-106 is hypothesized to exist early in the history of a well with other isotopes or by itself.
- U-235/8 appears only once to the southwest of the 111 tank.
- Eu-154 appears only once to the west of the 103 tank.

The fixed decay rate of the isotope(s) present is used to calculate the decay line (Figure 3). Table 7 illustrates the half-life of the isotopes encountered in this tank farm. When a contaminated interval contains multiple isotopes, the intensity of each isotope is included in the calculation for the decay curve that is then overlain on the GTP plot. When the decay curve does not fit with the GTP values over the entire timeframe, then it is usually fit to the later years in order to align the data so trends can be observed. When the decay curve fits the GTP plot, a stable condition is said to exist. When the decay curve does not fit the GTP plot, stability cannot be established.

Table 7. Half-life of Isotopes Identified or Hypothesized to be present in the BY Tank Farm

Isotope	Half-life Years
^{137}Cs	30.17
^{60}Co	5.27
^{125}Sb	2.77
^{154}Eu	8.5
$^{235/8}U$	7.00E+08/4.7E+09
^{106}Ru	1.02

3.2 Depth of Contamination:

The range in depth of contamination is variable throughout the BY Tank Farm as determined by gross gamma ray logging, which is less sensitive than SGLS analysis. The following general statements are from review of the gross gamma ray logging data. In general, Cs-137 occurs in the top 20 feet of the subsurface throughout the tank farm. Contamination is deepest and mostly continuous from surface to total depth of logging around tank 103 in the northeast corner of the tank farm and shallowest in the northwest corner of the tank farm around tank 112. Contamination is also deep around the 109, 108, and 107 tanks. Contamination commonly occurs from 40 to 80 feet throughout the farm, often as deep as 100 feet at various locations. The top of contamination identified in wells within the BY Tank Farm is shown in Figure 4, and the bottom of the contamination identified in these wells is shown in Figure 5. The range in depth of contamination varies according to localized areas of the tank farm. A significant portion of the contamination appears in two zones separated by 10 to 30 feet. The top zone is usually from surface to 10 feet, with the top of the second zone starting at 20 to 40 feet and ending at 80 to 100 feet. The majority of these split zones occur around the 103 tank and on all sides of the 107, 108, and 109 tanks and around the 111 tank. Occasionally, wells have contamination from surface to 40 or 60 feet. These occur primarily at the east-end of the tank farm.

Caution must be used when relating GTP values in zones recorded with different probe types since they were designed to read different intensities of contamination. There are isolated areas of high GTP throughout the tank farm, surrounded by areas of lower level contamination. Well 22-03-05 stands out as one with very high GTP over several depth intervals. It has GTP values that range from 350 to 170,000 ft*c/s detected with the Green GM probe, over a depth range from 0 to 85 feet. A series of wells located between the 112, 109, 108, and 105 tanks also have high GTP values ranging from 10,000 to 200,000 ft*c/s with data collected using the NaI probe. Many of the high readings taken with both the Green GM and the NaI probes were obtained even though the readings exceeded or nearly exceeded the upper detection threshold. The distribution of GTP values with depth range (in order of depth range) and contributing isotope(s) is shown in Table 8. Figure 6 shows the location and GTP values for these wells. Wells with contamination in excess of 10,000 ft*c/s are presented in Figure 7. These higher levels of contamination occur primarily from the west side of the 109 tank to the east side of the 108 tank and to the west and southeast of the 103 tank.

Table 8. BY Tank Farm Isotope Depth Range

Borehole Number	*Probe Type	Zone Depth feet	Max. GTP ft*c/s	Year Max. GTP	Isotopes Identified					
22-00-05	No data									
22-03-05	1	0-5	300	1984	^{137}Cs					
22-11-01	4	0-5	1,000	1975	^{137}Cs					
22-01-01	4	0-6	400	1985	^{137}Cs					
22-02-02	4	0-6	600	1975	^{137}Cs					
22-07-10	4	0-6	1,500	1975	^{137}Cs					
22-01-07	4	0-6	6,000	1975	^{137}Cs					
22-06-05	4	0-8	70	1975	^{137}Cs					
22-03-07	4	0-8	100	1975	^{137}Cs					
22-03-08	4	0-8	200	1975	^{137}Cs					
22-04-09	4	0-8	200	1984	^{137}Cs					
22-04-11	4	0-8	200	1984	^{137}Cs					
22-06-07	4	0-8	200	1984	^{137}Cs					
22-08-05	4	0-8	200	1975	^{137}Cs					
22-03-10	4	0-8	300	1975	^{137}Cs					
22-06-01	4	0-8	400	1984	^{137}Cs					
22-08-07	4	0-8	500	1975	^{137}Cs					
22-08-06	4	0-8	1,200	1975	^{137}Cs					
22-11-09	4	0-8	8,000	1975	^{137}Cs					
22-08-12	4	0-8	10,000	1989	^{137}Cs					
22-07-09	4	0-9	2,500	1984	^{137}Cs					
22-01-03	4	0-10	100	1975	^{137}Cs					
22-09-05	4	0-10	100	1975	^{137}Cs					
22-11-08	4	0-10	100	1975	^{137}Cs					
22-05-05	4	0-10	120	1975	^{137}Cs					
22-00-10	4	0-10	150	1975	^{137}Cs					
22-00-04	4	0-10	200	1975	^{137}Cs					
22-02-07	4	0-10	200	1986	^{137}Cs					
22-03-01	4	0-10	200	1986	^{137}Cs					
22-06-11	4	0-10	200	1975	^{137}Cs					
22-02-05	4	0-10	300	1975	^{137}Cs					
22-07-01	4	0-10	300	1975	^{137}Cs					
22-02-09	4	0-10	400	1986	^{137}Cs					
22-02-01	4	0-10	800	1985	^{137}Cs					
22-03-04	4	0-10	900	1975	^{137}Cs					
22-03-06	4	0-10	900	1975	^{137}Cs					
22-01-10	4	0-10	1,500	1975	^{137}Cs					

22-09-11	4	0-10	1,500	1975	^{137}Cs					
22-12-07	4	0-10	1,500	1984	^{137}Cs					
22-09-02	4	0-10	2,000	1975	^{137}Cs					
22-11-05	4	0-10	3,000	1975	^{137}Cs					
22-08-02	4	0-10	20,000	1993	^{137}Cs					
22-10-09	4	0-10	20,000	1975	^{137}Cs					
22-08-09	4	0-10	80,000	1984	^{137}Cs					
22-05-01	4	0-10	130,000	1985	^{137}Cs					
22-12-03	4	0-10	200,000	1980	^{137}Cs					
22-03-09	4	0-11	2,000	1975	^{137}Cs					^{154}Eu
22-08-01	4	0-12	200,000	1989	^{137}Cs					
22-00-02	4	0-14	600	1975	^{137}Cs					
22-01-04	4	0-15	1,700	1975	^{137}Cs					
22-12-05	4	0-20	1,000	1975	^{137}Cs					
22-12-06	4	0-20	8,000	1975	^{137}Cs					
22-11-01	4	5-10	900	1975	^{137}Cs					
22-03-05	1	5-15	350	1980	^{137}Cs					
22-07-10	4	6-12	2,000	1975	^{137}Cs					
22-01-01	4	6-15	50	1975	^{137}Cs					
22-01-07	4	6-15	100	1975	^{137}Cs					
22-02-02	4	6-18	300	1975	^{137}Cs					
22-07-02	4	6-20	200	1975	^{137}Cs					
22-08-06	4	8-18	500	1975	^{137}Cs					
22-03-10	4	8-30	170	1975	^{137}Cs					
22-07-09	4	9-17	1,400	1975	^{137}Cs					
22-09-02	4	10-14	300	1975	^{137}Cs					
22-02-01	4	10-20	200	1984	^{137}Cs					
22-12-03	4	10-20	300	1975	^{137}Cs					
22-04-11	4	10-25	200	1975	^{137}Cs					
22-03-04	4	10-30	800	1975	^{137}Cs					
22-03-09	4	11-24	2,600	1975				*^{106}Ru		
22-07-10	4	12-20	1,400	1975	^{137}Cs					
22-09-02	4	14-34	1,200	1975	^{137}Cs					
22-01-10	4	15-25	500	1975	^{137}Cs					
22-01-04	4	15-30	16,000	1975	^{137}Cs					
22-03-05	1	15-60	170,000	1980	^{137}Cs					
22-09-11	4	16-25	300	1975	^{137}Cs		*^{125}Sb			
22-09-08	4	16-30	80,000	1985	^{137}Cs					
22-07-09	4	17-36	50,000	1975	^{137}Cs					
22-08-06	4	18-29	400	1975	^{137}Cs					
22-11-01	4	19-28	4,000	1984	^{137}Cs					
22-02-09	4	20-26	200	1975			*^{125}Sb			
22-03-06	4	20-28	2,300	1975	^{137}Cs					
22-08-02	4	20-30	1,000	1975			*^{125}Sb			
22-07-10	4	20-30	1,600	1975	^{137}Cs					
22-04-01	4	20-35	250	1975				*^{106}Ru		
22-09-07	4	20-40	12,000	1975				*^{106}Ru		
22-08-01	4	22-32	500	1976		^{60}Co	*^{125}Sb			
22-03-09	4	24-52	29,000	1976		^{60}Co				

22-11-09	4	24-34	450	1975		^{60}Co				
22-09-01	4	24-35	250	1984				*^{106}Ru		
22-09-11	4	25-38	450	1975				*^{106}Ru		
22-08-12	4	25-40	300	1980	^{137}Cs					
22-01-10	4	25-44	550	1975	^{137}Cs	^{60}Co				
22-04-11	4	25-50	1,500	1975				*^{106}Ru		
22-02-09	4	26-34	450	1975			*^{125}Sb	*^{106}Ru		
22-06-05	4	28-36	500	1975		^{60}Co	*^{125}Sb			
22-07-10	4	30-44	1,400	1975	^{137}Cs					
22-07-07	4	30-54	2,500	1975	^{137}Cs		*^{125}Sb	*^{106}Ru		
22-01-04	4	30-60	1,400	1975		^{60}Co	*^{125}Sb			
22-08-01	4	32-42	2,400	1976		^{60}Co	*^{125}Sb			
22-02-09	4	34-44	1,800	1975			*^{125}Sb	*^{106}Ru		
22-11-09	4	34-46	250	1975		^{60}Co				
22-04-01	4	35-45	150	1975				*^{106}Ru		
22-08-05	4	36-45	250	1975		^{60}Co				
22-03-06	4	37-48	13,000	1975	^{137}Cs	^{60}Co	^{125}Sb			
22-09-11	4	38-52	3,500	1975				*^{106}Ru		
22-09-07	4	40-50	9,000	1976				*^{106}Ru		
22-08-12	4	40-51	3,000	1975		^{60}Co	*^{125}Sb			
22-06-07	4	40-52	300	1975	^{137}Cs					
22-07-01	4	40-52	800	1976	^{137}Cs					
22-02-01	4	40-53	3,200	1975	^{137}Cs					
22-01-07	4	40-55	200	1975		^{60}Co				
22-09-01	4	40-55	2,200	1975			*^{125}Sb	*^{106}Ru		
22-03-04	4	40-55	2,800	1975			^{125}Sb			
22-07-05	4	40-57	3,800	1975		^{60}Co				
22-09-05	4	40-58	250	1975	^{137}Cs		*^{125}Sb			
22-03-08	4	40-60	1,300	1975		^{60}Co		*^{106}Ru		
22-00-01	4	40-65	250	1975	^{137}Cs					
22-00-03	4	40-80	3,000	1975		^{60}Co	^{125}Sb			
22-06-01	4	42-52	200	1975		^{60}Co				
22-08-01	4	42-59	25,000	1975		^{60}Co	*^{125}Sb			
22-09-02	4	42-64	500	1975				*^{106}Ru		
22-09-08	4	43-52	150	1981		^{60}Co				
22-02-09	4	44-52	2,500	1975	^{137}Cs	^{60}Co		*^{106}Ru		
22-08-02	4	44-60	15,000	1975		^{60}Co	*^{125}Sb			
22-08-05	4	45-53	700	1975		^{60}Co				
22-10-05	4	45-55	200	1975		^{60}Co				
22-00-02	4	45-56	1,300	1975		^{60}Co	^{125}Sb			
22-10-07	4	45-65	200	1983		^{60}Co				
22-07-02	4	42-95	2,800	1976		^{60}Co				
22-08-06	4	46-54	150	1975	^{137}Cs	^{60}Co				
22-03-07	4	47-62	1,300	1975		^{60}Co	*^{125}Sb			
22-03-06	4	48-60	2,400	1975			*^{125}Sb	*^{106}Ru		
22-00-04	4	48-70	500	1975		^{60}Co	*^{125}Sb			
22-09-07	4	50-64	2,700	1976			*^{125}Sb	*^{106}Ru		
22-08-12	4	51-60	3,000	1975		^{60}Co				
22-06-01	4	52-65	600	1975		^{60}Co		*^{106}Ru		

22-07-01	4	52-70	3,500	1975		^{60}Co				
22-06-07	4	52-80	1100	1979		^{60}Co				
22-08-05	4	53-56	1,000	1975		^{60}Co				
22-08-06	4	54-63	200	1975		^{60}Co				
22-02-09	4	55-65	100	1975		^{60}Co				
22-05-09	4	55-90	1,000	1975		^{60}Co				
22-02-01	4	55-75	200	1975				*^{106}Ru		
22-10-05	4	55-75	300	1979		^{60}Co				
22-03-04	4	55-85	900	1975		^{60}Co				
22-00-02	4	56-64	1,200	1975			*^{125}Sb	*^{106}Ru		
22-11-08	4	56-66	120	1975		^{60}Co			$^{235/8}$U	
22-07-05	4	57-65	1,200	1982		^{60}Co				
22-10-10	4	58-76	1,500	1975		^{60}Co				
22-08-01	4	59-82	12,000	1975		^{60}Co	*^{125}Sb			
22-08-12	4	60-70	1,000	1976		^{60}Co				
22-03-05	1	60-85	1,700	1980	^{137}Cs					
22-03-06	4	60-94	4,300	1975		^{60}Co	*^{125}Sb	*^{106}Ru		
22-08-02	4	62-72	10,000	1976		^{60}Co	*^{125}Sb			
22-07-09	4	62-74	2,200	1976	^{137}Cs					
22-03-07	4	62-90	1,100	1975		^{60}Co		*^{106}Ru		
22-08-06	4	63-73	900	1975		^{60}Co				
22-08-05	4	63-74	900	1975		^{60}Co				
22-06-05	4	64-84	3,700	1984		^{60}Co				
22-00-02	4	64-96	1,800	1975		^{60}Co				
22-07-05	4	65-78	900	1986		^{60}Co				
22-08-12	4	70-82	500	1980		^{60}Co				
22-00-01	4	70-84	70	1975	^{137}Cs					
22-00-04	4	70-85	1,000	1975		^{60}Co		*^{106}Ru		
22-06-09	4	70-90	650	1975				*^{106}Ru		
22-07-01	4	70-92	3,000	1975		^{60}Co				
22-08-09	4	72-84	150	1975	^{137}Cs			*^{106}Ru		
22-08-02	4	72-84	4,000	1985		^{60}Co				
22-08-06	4	73-83	450	1975		^{60}Co				
22-08-05	4	74-84	200	1991		^{60}Co				
22-07-09	4	74-84	1,200	1982		^{60}Co				
22-04-09	4	75-95	1,800	1980		^{60}Co				
22-09-08	4	76-90	100	1985		^{60}Co				
22-03-09	4	78-82	16,000	1976		^{60}Co				
22-03-09	4	48-95	5,000	1979		^{60}Co				
22-02-01	4	80-96	550	1975		^{60}Co		*^{106}Ru		
22-03-08	4	80-98	100	1975		^{60}Co				
22-07-07	4	80-98	1,800	1976		^{60}Co	^{125}Sb			
22-00-03	4	80-117	12,000	1975		^{60}Co				
22-08-01	4	82-95	450	1987		^{60}Co	*^{125}Sb			
22-07-09	4	84-94	1,000	1985		^{60}Co				
22-00-01	4	84-100	70	1975	^{137}Cs					
22-08-02	4	84-100	3,000	1975		^{60}Co				
22-07-05	4	90-100	500	1975	^{137}Cs					
22-04-11	4	90-100	1,000	1975		^{60}Co				

22-07-09	4	94-100	900	1986		^{60}Co				
22-03-06	4	94-100	1,000	1975			^{*125}Sb			
22-04-09	4	105-120	500	1984		^{60}Co				
22-00-03	4	117-128	1,800	1975		^{60}Co				
22-00-03	4 .	128-140	1,100	1975		^{60}Co	^{*125}Sb			

*Probe type: 1 = Green GM, moderately sensitive; reads moderate levels of gamma ray activity.
4 = NaI, most sensitive, reads lowest level of gamma ray activity.
Caution must be used when relating GTP values in zones recorded with different probe types.

*Currently, isotopes cannot be identified from gross gamma ray data alone; therefore, isotopes with a rapid rate of decay, such as Ru-106, or at low enough levels to decay below detection limits, may not be identified if the period of instability is prior to the collection of SGLS data.

3.3 Isotopes Identified:

Seven man-made isotopes are known or hypothesized to be present in the BY Tank Farm at or above the detection limit for the gross gamma ray logging equipment. They are listed in Table 7 along with their half-life. Cesium-137 and Co-60 are the most common isotopes found in the BY Tank Farm and occur throughout the farm at varying depths and intensities. The Cs-173 occurs primarily in the top 20 feet of the subsurface usually by itself, and Co-60 occurs from 20 to 140 feet, often by itself but commonly with other isotopes. It is found deeper than 100 feet in only two wells: 22-00-03 and 22-04-09. Antimony-125 occurs between 16 and 140 feet and is localized primarily at the southeast side of the 103 tank and the southeast and north regions of the 109 tank. Antimony-125 is identified in only six wells; the rest of the occurrences are hypothesized. Only in well 22-00-03 is Sb-125 hypothesized to occur deeper than 100 feet. Uranium-235/8 appears only once at 56 to 66 feet in well number 22-11-08. Europium-154 appears only once at 0 to 11 feet in well number 22-03-09. Ruthenium-106 is hypothesized to have been present in a number of wells, mostly around the 109 and 103 tanks with some occurrences in the southeast end of the tank farm. The half-life of Ru-106 is short (1.02 years) and Ru-106 is no longer detectable in the wells by the HPGe detector. However, it was an inventoried isotope and the decay line calculated for Ru-106 matches well with the GTP calculations in most wells. The distribution and depth to top of the isotopes that occur in the BY Tank Farm are shown in Figure 4.

3.4 Timeframe:

The time range over which data were evaluated is limited from when gross gamma ray digital data were first captured in 1975 to the last digital data-collecting event in 1994. Three general conditions are observed concerning the life cycle of contamination events with respect to the timeframe in which digital data are available for analysis. Within this timeframe, the data appear to represent:

- The middle or end of a period (initiated prior to inception of digital data collection) where subsurface conditions were unstable and the beginning of apparent stability.
- Stable subsurface conditions at the beginning of data collection, whereby an unstable condition develops (indicated by a rate of change that is inconsistent with the decay rate of known isotopes in the well), followed by apparent stability.
- Stable subsurface conditions at the beginning of data collection, whereby an unstable condition develops (indicated by a rate of change that is inconsistent with the decay rate of known isotopes in the well) that does not become stable within the timeframe of data collection.

There is insufficient information available to determine if contamination at depth may be the result of well installation activities.

Usually, the maximum GTP calculated for the gross gamma ray data seems to coincide with the start of digital data collection. The exceptions are listed in Table 9.

Table 9. BY Tank Farm Zones with Highest GTP After Start of Data Collection

Borehole Number	Total Depth feet	Subsurface Condition Category	Zone Depth feet	Max. GTP ft*c/s	Year Max. GTP	Isotopes Identified
22-01-01	100	TF Activity	0-6	400	1985	^{137}Cs
22-02-01	100	TF Activity	0-10	800	1985	^{137}Cs
		TF Activity	10-20	200	1984	^{137}Cs
22-02-07	150	TF Activity	0-10	200	1986	^{137}Cs
22-02-09	100	TF Activity	0-10	400	1986	^{137}Cs
22-03-01	95	TF Activity	0-10	200	1986	^{137}Cs
22-03-05	100	Undetermined	0-5	300	1984	^{137}Cs
22-03-09	100	Unstable early	24-52	29,000	1976	^{60}Co; $^{*125}Sb$; $^{*106}Ru$
		Unstable	48-95	16,000	1976	^{60}Co; $^{*125}Sb$
22-04-09	100-125	TF Activity	0-8	200	1984	^{137}Cs
		Unstable early	75-95	1,800	1980	^{60}Co
		Stable	105-120	500	1984	^{60}Co
22-04-11	100	TF Activity	0-8	200	1984	^{137}Cs
22-05-01	100	TF Activity	0-10	130,000	1985	^{137}Cs
22-06-01	100	TF Activity	0-8	400	1984	^{137}Cs
22-06-07	140	TF Activity	0-8	200	1984	^{137}Cs
		Unstable early	52-80	1,100	1979	^{60}Co
22-07-01	100	Unstable early	40-52	800	1976	^{137}Cs
22-07-02	100	Unstable	42-95	2,800	1976	^{60}Co
22-07-07	100	Unstable	80-98	1,800	1976	^{60}Co
22-07-09	100	TF Activity	0-9	2,500	1984	^{137}Cs
22-08-01	100	TF Activity	0-12	200,000	1989	^{137}Cs
		Stable	22-32	500	1976	^{60}Co; ^{125}Sb
		Stable	32-42	2,400	1976	^{60}Co; ^{125}Sb
22-08-02	100	TF Activity	0-10	20,000	1993	^{137}Cs
22-08-09	100	TF Activity	0-10	80,000	1984	^{137}Cs
22-08-12	105	TF Activity	0-8	10,000	1989	^{137}Cs
		Unstable early	25-40	300	1980	^{137}Cs
		Unstable early	60-82	1,000	1976	^{60}Co
22-09-02	100	TF Activity	0-10	2,000	1984	^{137}Cs
22-09-07	97	Unstable early	40-50	9,000	1976	$^{*106}Ru$
		Unstable early	50-64	2,700	1976	$^{*125}Sb$; $^{*106}Ru$
22-09-08	98	Undetermined	16-30	80,000	1985	^{137}Cs
		Stable	43-52	150	1981	^{60}Co
		Undetermined	76-90	100	1985	^{60}Co
22-10-05	100	Unstable early	55-75	300	1979	^{60}Co
22-10-07	100	Unstable early	45-65	200	1983	^{60}Co
22-11-01	100	Unstable	19-28	4,000	1984	^{137}Cs
22-12-03	100	TF Activity	0-10	200,000	1980	^{137}Cs
22-12-07	100	TF Activity	0-10	1,500	1984	^{137}Cs

*Currently, isotopes cannot be identified from gross gamma ray data alone; therefore, isotopes with a rapid rate of decay, such as Ru-106, or at low enough levels to decay below detection limits, may not be identified if the period of instability is prior to the collection of SGLS data.

3.5 Unstable Zones:

Periods of instability are generally complex and occur throughout the timeframe over which digital data were collected. For many unstable zones, data collection started in 1975 while conditions in the zone were still unstable. See Table 10 for a list of wells that had unstable zones of contamination and details of the instability. Well 22-11-01 represents an unusual occurrence where Cs-137 appears stable in the zone from 19 to 28 feet until 1982, and becomes unstable after 1982. Cesium-137 appears as stable in other wells in the BY Tank Farm.

Table 10. BY Tank Farm Unstable Zone Parameters

Borehole Number	Total Depth feet	Subsurface Condition Category	Zone Depth feet	Interval of Instability	Isotopes Identified	**Comment
22-00-02	100	Unstable	64-96	1979-1994	^{60}Co	^{137}Cs decay curve fits, but was not used as ^{137}Cs was not id'd by the SGLS
22-00-03	145	Unstable early	80-117	1975-1976	^{60}Co	
22-03-09	100	Unstable early	24-52	1975-1977	^{60}Co; ^{*125}Sb; ^{*106}Ru	Incr. 1975-1976; decr. 1976-1977
		Unstable early	44-52	1975-1984	^{*106}Ru	Incr. 1975-1980; sharp incr. 1980-mid 1982
		Unstable	78-92	1975-1985	^{60}Co; ^{*125}Sb	Incr. 1975-1979; decr. 1979-1985
		Unstable	48-95	1975-1990	^{60}Co	Incr. 1975-1976; stable 1976-1978; unstable decr. 1978-1990; stable 1990-1994
22-04-09	100-125	Unstable early	75-95	1974-1984	^{60}Co	Incr. 1979-1980; decr. 1980-0982; decr. 1982-1984
22-05-09	100	Unstable	55-90	1975-1985	^{60}Co	Decr.
22-06-05	100	Unstable	36-50	1978-1981	^{60}Co; ^{*125}Sb	Decr.
		Unstable	62-84	1986-mid1991	^{60}Co	Decr.
		Unstable	28-84	1975-mid1975	^{60}Co; ^{*125}Sb	Incr.
		Unstable	40-84	1979-1994		Decr. mid 1975-1976; decr. 1979-1994
22-06-07	140	Unstable early	40-52	1975-mid1982	^{137}Cs	Decr.
		Unstable early	52-64	1975-1985	^{60}Co	Incr. 1975-1977; decr. 1977-mid1977; incr. mid1977-1979; decr. 1979-1985
		Unstable early	64-80	1975-1984	^{60}Co	Incr. 1975-1981; decr. 1981-1984
		Unstable early	52-80	1975-mid1979	^{60}Co	Incr. 1975-1977; decr. 1977-mid1977; incr. mid1977-1979
22-06-09	100	Unstable early	70-90	1976-1976	^{*106}Ru	Incr. 1975-mid1975; decr. mid1975-1976
22-07-01	100	Unstable early	40-52	1975-1981	^{137}Cs	Incr. 1975-1976; decr. 1976-1981
22-07-02	100	Unstable early	42-53	1975-1994	^{60}Co	Incr. 1975-mid1975; decr. mid1975-1984; decr. 1981-1994
		Unstable early	53-70	1975-1994	^{60}Co	Incr. 1975-1979; rapid incr. 1979-early 1979; decr. early 1979-1981; decr. 1981-1994
		Unstable early	70-82	1980-mid1987	^{60}Co	Incr. 1980-1981; decr. 1981-1987
		Unstable early	82-95	1975-1987	^{60}Co	Decr. 1975-1980; incr. 1982-mid1983; decr. mid1983-1987
22-07-05	100	Unstable early	40-57	1975-1994	^{60}Co	Incr. 1975-mid1975; decr. mid1975-mid1978; incr. mid1978-1979; decr. 1979-1985
		Unstable early	57-65	mid1978-mid1986	^{60}Co	Incr. mid1978-mid1983; decr. mid1983-mid1986
		Unstable early	65-78	1981-mid1987	^{60}Co	Incr.
22-07-07	100	Unstable early	30-54	1980-1994	^{137}Cs; ^{*125}Sb; ^{*106}Ru	Step decr. 1980-1981; flat near 0 to 1994
		Unstable	80-98	1975-1985	^{60}Co; ^{125}Sb	Incr. 1975-1976; decr. 1976-1981; incr. 1981-mid1981; decr. mid1981-1985
22-07-09	100	Unstable	62-74	1975-1986	^{137}Cs	Incr. 1975-mid1976; decr. m1976-1986
		Unstable	74-84	1975-mid1988	^{60}Co	Incr. 1975-1979; decr. 1979-mid1980; incr. mid1980-1982; decr. 1982-mid1988
		Unstable	84-94	1982-1989	^{60}Co	Incr. 1982-1986; decr. mid1981-1985; decr. 1985-1994
		Unstable	94-100	1981-1990	^{60}Co	Incr. 1981-mid1981; decr. mid1981-mid1982; incr. 1984-mid1986; decr. mid1986-1990
22-08-01	100	Unstable	59-95	1975-1986	^{60}Co; ^{*125}Sb	Decr.

22-08-02	100	Unstable	44-62	1975-1994	^{60}Co; ^{*125}Sb	Decr. 1975-1982 flat near 0 1982-1994
		Unstable	62-72	1975-1994	^{*125}Sb	Incr. 1975-1977; decr. 1977-1994
		Unstable	72-84	1975-1994	^{*125}Sb	Decr. 1975-1981; incr. 1981-1985; decr. 1985-1994
		Unstable	84-100	1975-1994	^{*125}Sb	Decr. 1975-1988; incr. 1988-1991; decr. 1991-1994
22-08-05	100	Unstable early	63-74	1975-1986	^{60}Co	Decr.
		Unstable early	74-84	mid1984-1990	^{60}Co	Incr.
22-08-06	100	Unstable early	73-83	1975-1977	^{60}Co	Flat
22-08-09	100	Unstable early	72-84	1975-1976	^{137}Cs; ^{*106}Ru	Incr.
22-08-12	105	Unstable early	25-40	1975-1994	^{137}Cs	Incr. 1975-mid1976; decr. mid1976-1978; incr. 1978-mid1980; decr. mid1980-1983; flat near 0 1983-1994
		Unstable early	40-51	1975-1989	^{60}Co; ^{*125}Sb	Decr.
		Unstable early	51-60	1975-1983	^{60}Co	Decr. 1975-1979; incr. 1979-mid1983
		Unstable early	60-70	1975-1987	^{60}Co	Decr.
		Unstable early	70-82	1975-1983	^{60}Co	Incr.
22-09-07	100	Unstable early	20-40	mid1978-1982	^{*106}Ru	Decr.
		Unstable early	40-50	1975-1984	^{*106}Ru	Incr. 1975-1976; decr. 1980-1984
		Unstable early	50-64	1980-1990	^{*125}Sb; ^{*106}Ru	Decr.
22-09-11	100	Unstable early	38-52	1975-1976	^{*106}Ru	Decr.
22-10-05	100	Unstable early	55-75	1975-1979	^{60}Co	Incr.
22-10-07	100	Unstable early	45-65	1980-1994	^{60}Co	Incr. 1980-1983; decr. 1983-1985; flat near 0 1985-1994
22-10-10	100	Unstable early	58-76	1975-1980	^{60}Co	Decr.
22-11-01	100	Unstable	19-28	1982-1994	^{137}Cs	Incr. 1982-1984; decr. 1984-1994
22-11-09	100	Unstable early	34-46	1975-mid1978	^{60}Co	Flat

*Currently, isotopes cannot be identified from gross gamma ray data alone; therefore, isotopes with a rapid rate of decay, such as Ru-106, or at low enough levels to decay below detection limits, may not be identified if the period of instability is prior to the collection of SGLS data.

**Unless otherwise noted, the GTP plot decreases consistent with the decay curve of known isotopes.

5.0 Summary

A summary of the radionuclides present in the vadose zone of BY Tank Farm has been presented in this report. By integrating SGLS data with historical dry well surveillance data, knowledge is gained concerning the behavior of radionuclides in the vadose zone over time. The SGLS data allow a rigorous conclusion about the identity, character, and decay trends of isotopes present in a contaminated zone identified within the twenty-year period that the dry well data were collected.

Five subsurface conditions were discerned during the analysis of the historical dry well data: clean, stable, unstable/unstable early, tank farm activity, and undetermined. This classification reflects the conditions in which contamination is present (or not present) within the timeframe gross gamma ray data were collected electronically, but says nothing about the conditions within the subsurface today. However, an assumption that the trend of the data might continue unaltered seems reasonable, barring any event that changes the hydrogeologic or geochemical conditions in the subsurface. On the basis of the data available at the time and within the scope of this report, a statement cannot be made as to whether any of the isotopes present in the subsurface of the BY Tank Farm can be remobilized.

Three of the clean wells occur in the northwest corner of the tank farm, and two are south of the 104 tank. One third of the contaminated zones appear to exist under a stable condition. Within the timeframe that digital data are available, most of the zones that exhibit an unstable condition early on are currently stable and occur primarily in the west half of the tank farm and around the 103 and 106 tanks. Six wells currently exhibit unstable conditions. Additional wells may be exhibiting unstable conditions, but the contamination levels are too low to make a rigorous determination. There were only six (three around the 103 tank) zones spread throughout the tank farm where the subsurface condition is undetermined. More than half of the wells have indications of tank farm activity at the surface and occur throughout the tank farm.

The most common isotopes present throughout the subsurface of the BY Tank Farm are Cs-137 and Co-60. Cesium-137 occurs in the top 20 feet of the subsurface throughout the tank farm in all but ten of the contaminated wells. Cobalt-60 occurs through out the tank farm below 20 feet, primarily around tanks 101, 103, 107, 108, and 109, as well as to the west of tanks 110 and 111. Anitmony-125 occurs below 15 feet and is located primarily around the 109 tank and the southeast region of the 103 tank. It is often hypothesized to have been present since, by the time of the SGLS analysis, levels decayed to below the detection threshold. In a few instances, Sb-125 was not identified by the SGLS, yet the levels of radioactivity in four zones in four wells prior to the SGLS analysis suggest that there was sufficient Sb-125 present to have been identified by SGLS, given stable conditions. These zones are: 48 to 70 feet in well 22-00-04, 34 to 44 feet in well 22-02-09, 42 to 59 feet in well 22-08-01, and 40 to 51 feet in well 22-08-12. Further analysis of these zones may be warranted. Uranium-235/8 is identified only in well 22-11-08 from 56 to 66 feet. Europium-154 is identified only in well 22-03-09 from 0 to 11 feet. Ruthenium-106 is hypothesized to have existed in the subsurface, although it is no longer at detectable levels, primarily around the 103 and 109 tanks from 11 to 96 feet.

Two areas of the tank farm have wells with contamination at greater than 10,000 ft*c/s GTP. They are from the east of the 109 tank to the west of the 108 tank and southeast of the 103 tank. The contamination occurs primarily in two zones, surface (0 to 10 feet), and between 20 and 40 feet to between 80 and 100 feet except in well 22-03-05 where the contamination is fairly consistent from the surface to 85 feet. Well 22-03-05 has high level contamination, but it is currently stable. The wells containing high levels of contamination in these areas of the tank farm are surrounded by wells with significantly lower levels of contamination or no contamination at all and may indicate proximity to point sources. These wells with high levels of contamination typically have very high levels of Cs-137 and are many times surrounded by wells with different isotopes. It may be possible that the presence of other isotopes is masked by the strong presence of Cs-137.

Nine wells have unstable conditions at the end of data collection in 1994. Of these, the contamination in six wells is less than 100 ft*c/s. Well 22-08-02 is currently unstable from 44 to 100 feet and has contamination levels just under 4,000 ft*c/s. Well 22-03-09 is currently unstable with contamination less than 500 ft*c/s that has passed through the bottom of the well in 1993 and appears to continue moving down at an estimated rate of 2 feet per year.

Isotopes appear to move through the vadose at different rates depending on subsurface conditions. In general and given similar conditions, of the isotopes found or hypothesized to be present in the BY Tank Farm, Cs-137 usually moves downward the least and U-235/8 usually moves the deepest, with mobility of the other isotopes falling somewhere in between. Cs-137 occurs throughout the subsurface of the tank farm, both by itself and with other isotopes. It occurs primarily by itself in the top 20 feet of 53 wells. This may indicate a high retention factor related to Cs-137 and soil interaction. U-235/8 occurs at a fairly shallow depth in only one well in the BY Tank Farm. The other isotopes identified through SGLS analysis, and those hypothesized and supported by tank inventories, occur throughout the tank farm from 20 to 140 feet. It is not known if contamination exists deeper than the bottom of any given well although it is suspected in wells 22-03-09, 22-07-02, 22-07-09, and 22-08-02. Several anomalies present in the data seem to stand out:

- In wells 22-00-01, 22-03-05, 22-07-05, and 22-07-09, Cs-137 exists deep in the wells (as deep or deeper than Co-60) with little or no Cs-137 remaining in the upper portions of the borehole.
- In well 22-00-02, Cs-137 is not identified with the SGLS analysis in the zone from 64 to 96 feet. Even though the decay rate for Cs-137 fits the GTP plot, Cs-137 is not listed as existing in this zone.
- In well 22-00-10, Cs-137 was identified at 8 pCi/g during SGLS analysis and should appear in the gross gamma ray logs at 46 feet, but doesn't.
- Occasionally, Cs-137 and Co-60 are viewable in the gross gamma ray data and not in the SGLS data.
- Ru-106 is very mobile according to the current understanding of chemistry, and should therefore be found deeper and more laterally extensive than is indicated in the BY Tank Farm.
- In the GTP plot for the surface contamination in the majority of wells is what appears to be a data spike occurring in or near 1985 (Figure 8). The GTP values range from approximately 300 ft*c/s to 9000 ft*c/s with the highest values occurring to the southwest of the 101 and 112 tanks. These spikes in the data are noticeably absent from wells near the center of the tank farm and to the southwest around the 110 tank. In well 22-11-01, the spike appears in GTP in two additional plots below the surface to 29 feet. In several wells, more than one spike appears in the GTP plot of the surface correlating with different timeframes.

Limits in the data available for examination make evaluation of the data incomplete and as such, the apparent anomalies are unable to be explained. Information as to how or whether geology and/or geochemistry effect the direction and extent of isotope migration in the subsurface is not considered in this report.

References

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WMNW/TRS-ES-VZMA-002; Randall, R. R., R. K. Price, "Monitoring Results for the SX Single Shell Tank Farm Dry Well Gamma Ray Surveillance Log Surveys," 1998, Waste Management Federal Services, Inc., Northwest Operations, Richland, Washington.

WMNW 1998, "Analysis of Historical Gross Gamma Logging Data from BY Tank Farm," Project 772028, Task 23020001, 3 Rivers Scientific, West Richland, Washington.

Errata:

At the time of publication, the following errors were noted in the enclosed figures:

Figure 2:
Missing scale; map is at same scale as the other maps

Figure 6:
22-00-04 has Ru-106 48-85'
22-02-01 has Co-60 40-96'
22-03-07 has Ru-106 47-90'

Figure 7:
Sub-title should read all readings obtained with NaI probe except where noted.
22-03-05 should read Green GM probe 0-5' 300; 5-15' 350; 15-60' 170K, 60-85' 1.7K
22-08-01 should read 59-82' 12K

Figure 8:
22-00-10 should read 1985 (400)
22-03-08 should read 1985 (1200); 1987 (1500); 1993 (1400)
22-12-05 should read 1984-85 (3500-3800)
22-12-09 should not have anything

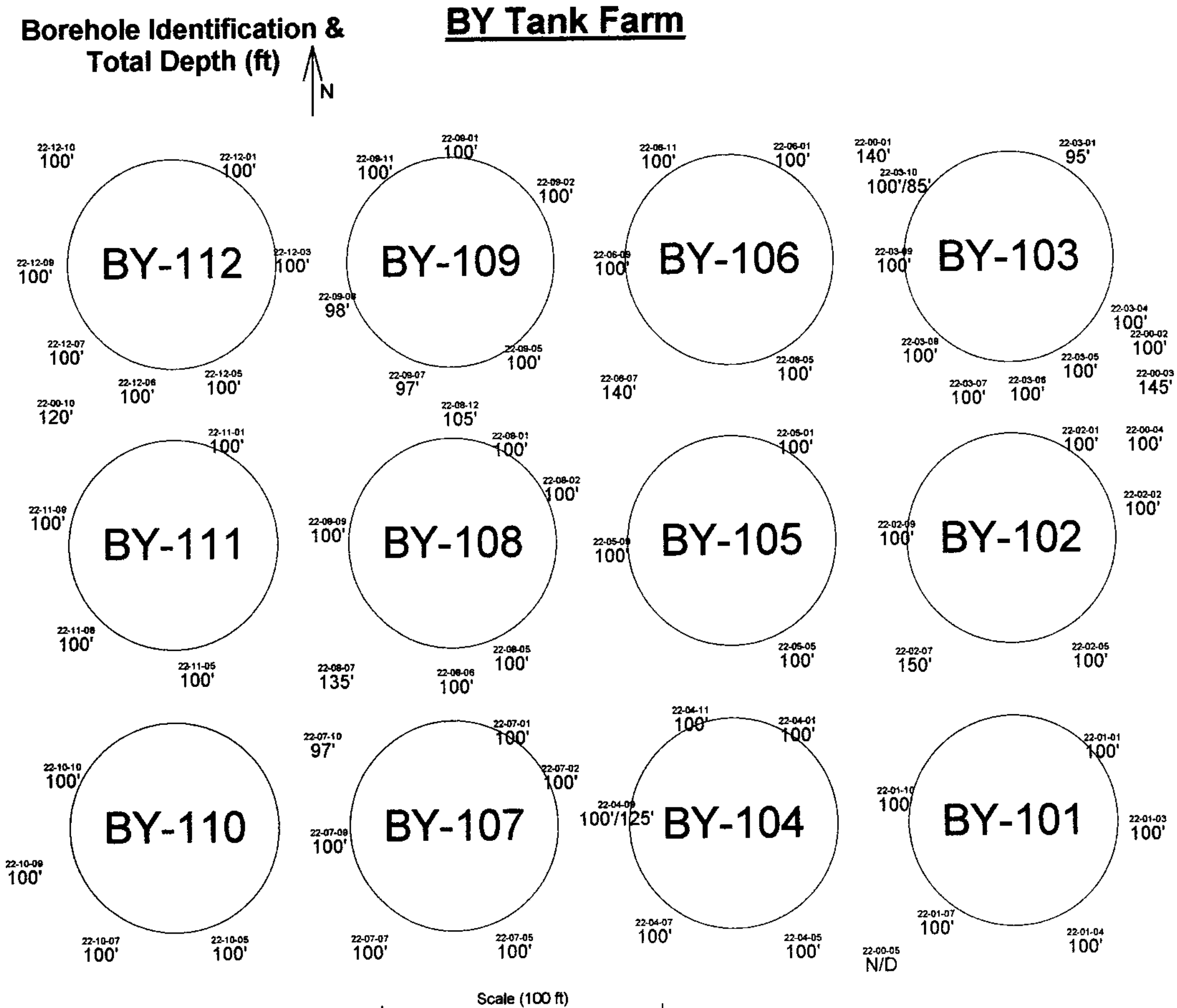


Figure 1. BY Tank Farm Borehole Identification and Total Depth

N/D = No Data

BY-Tot-Dep.jnb

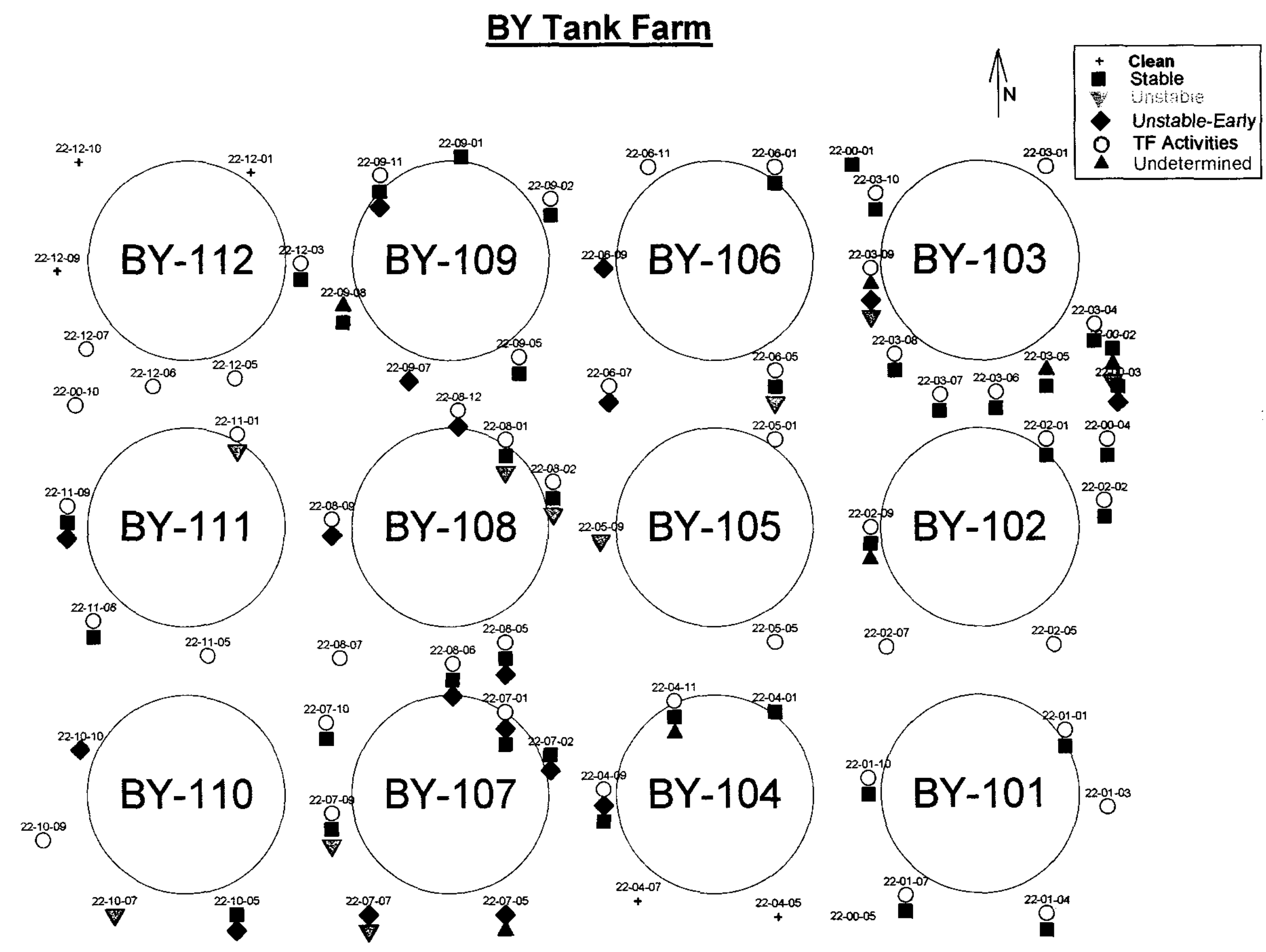


Figure 2. BY Tank Farm Radiation Zone Conditions

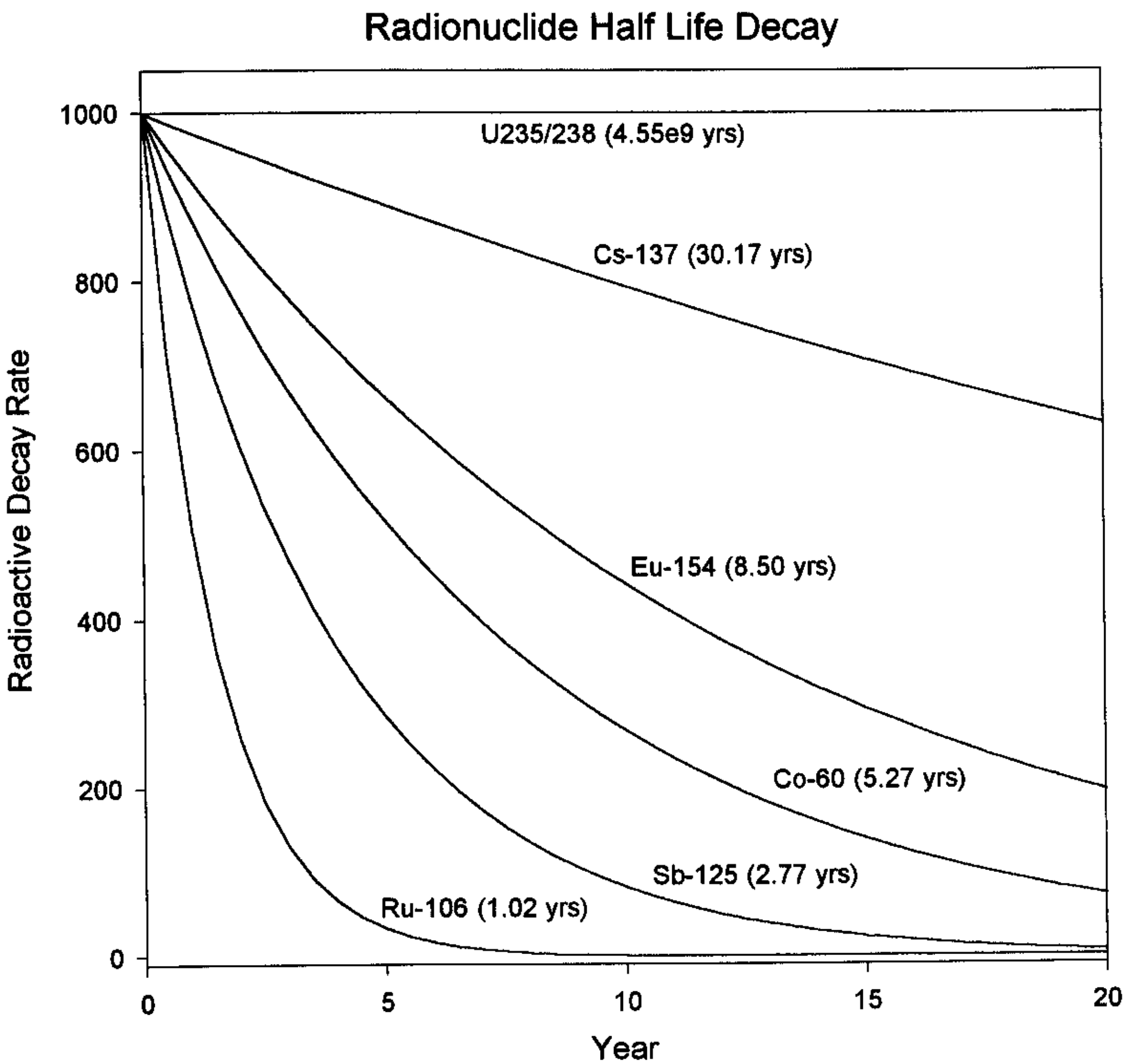


Figure 3. Isotope Half-life Decay Curves

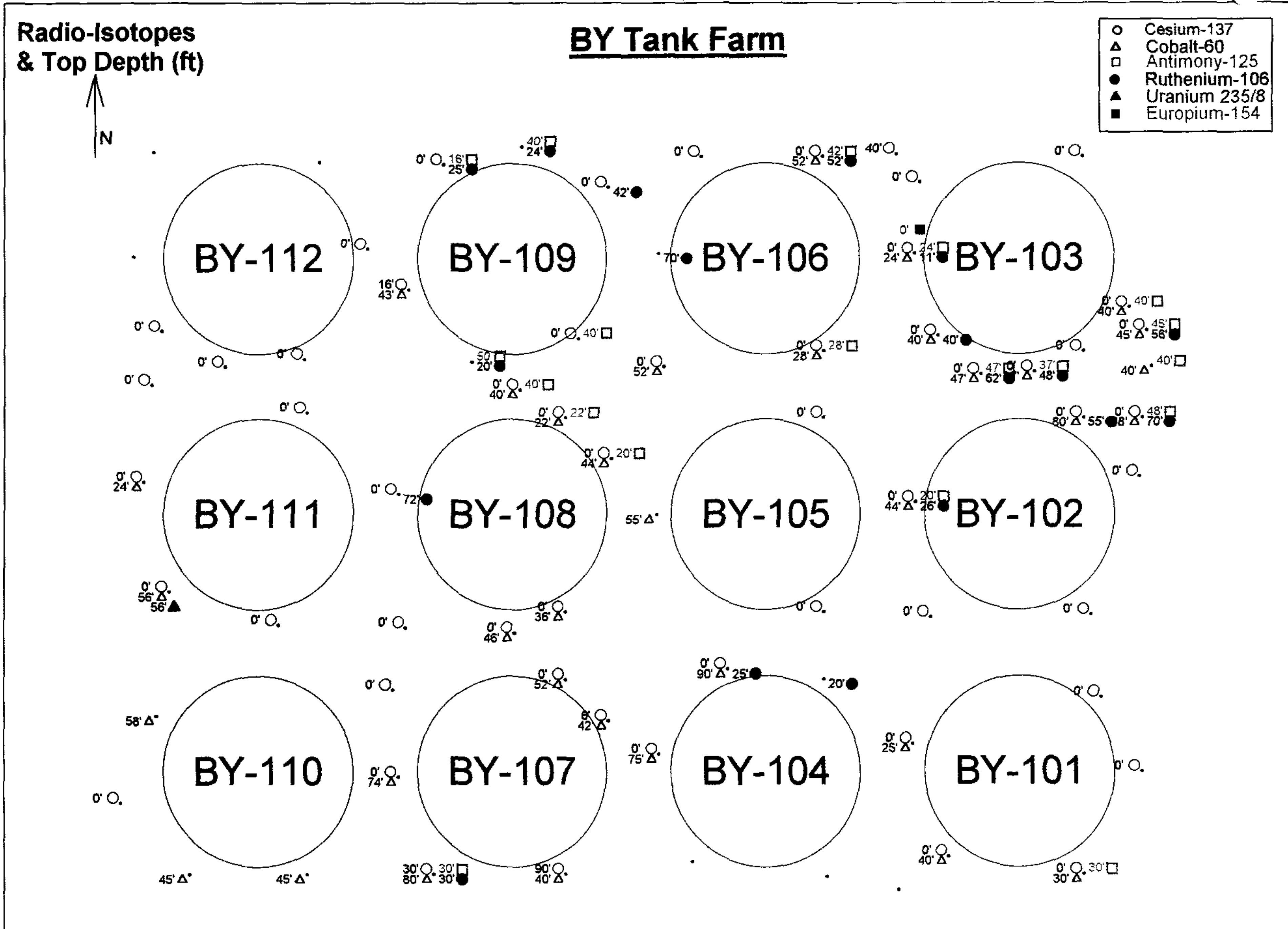


Figure 4. BY Tank Farm Isotope Top Depth

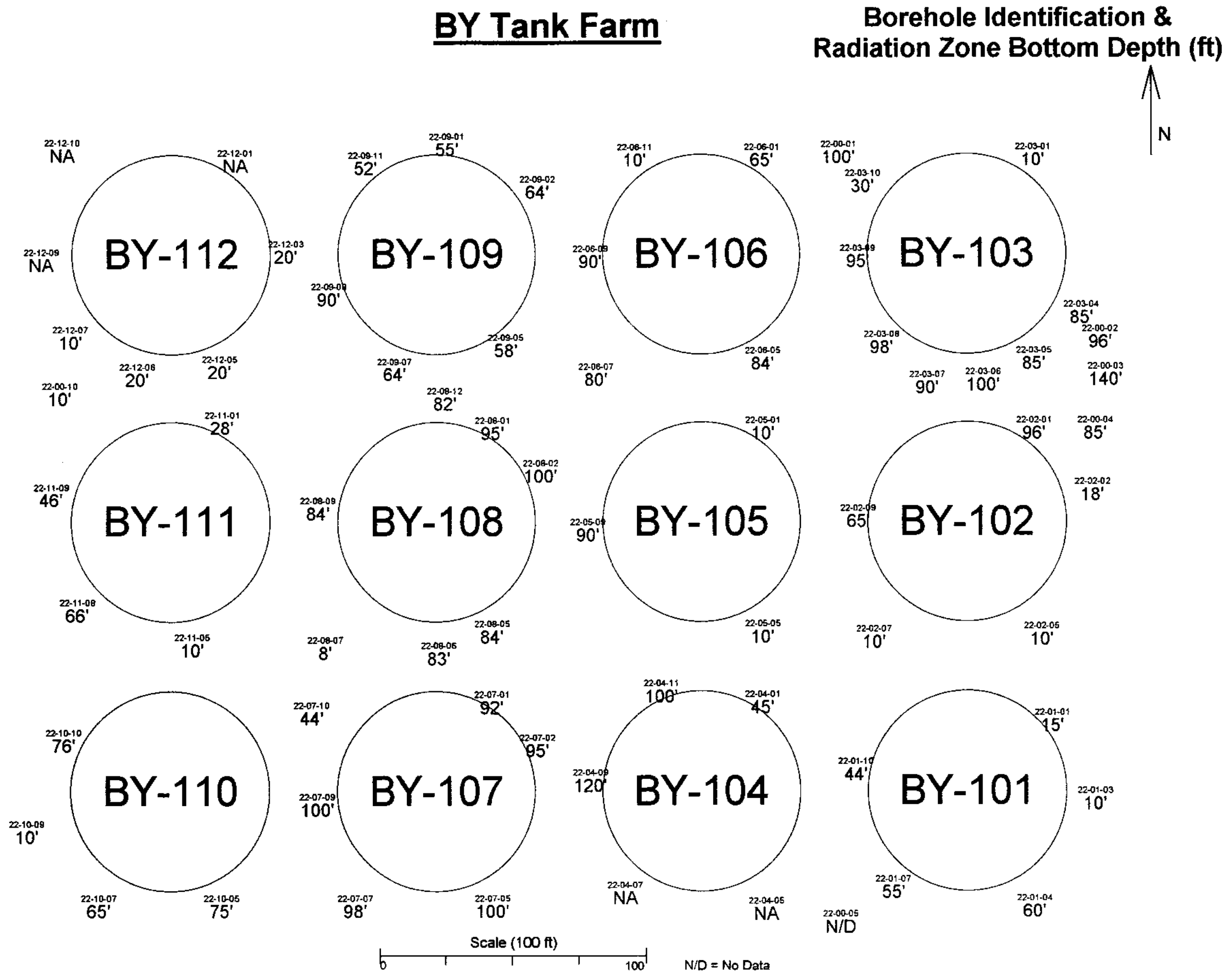


Figure 5. BY Tank Farm Radiation Zone Bottom Depth

BY-Bot-Rad.jnb

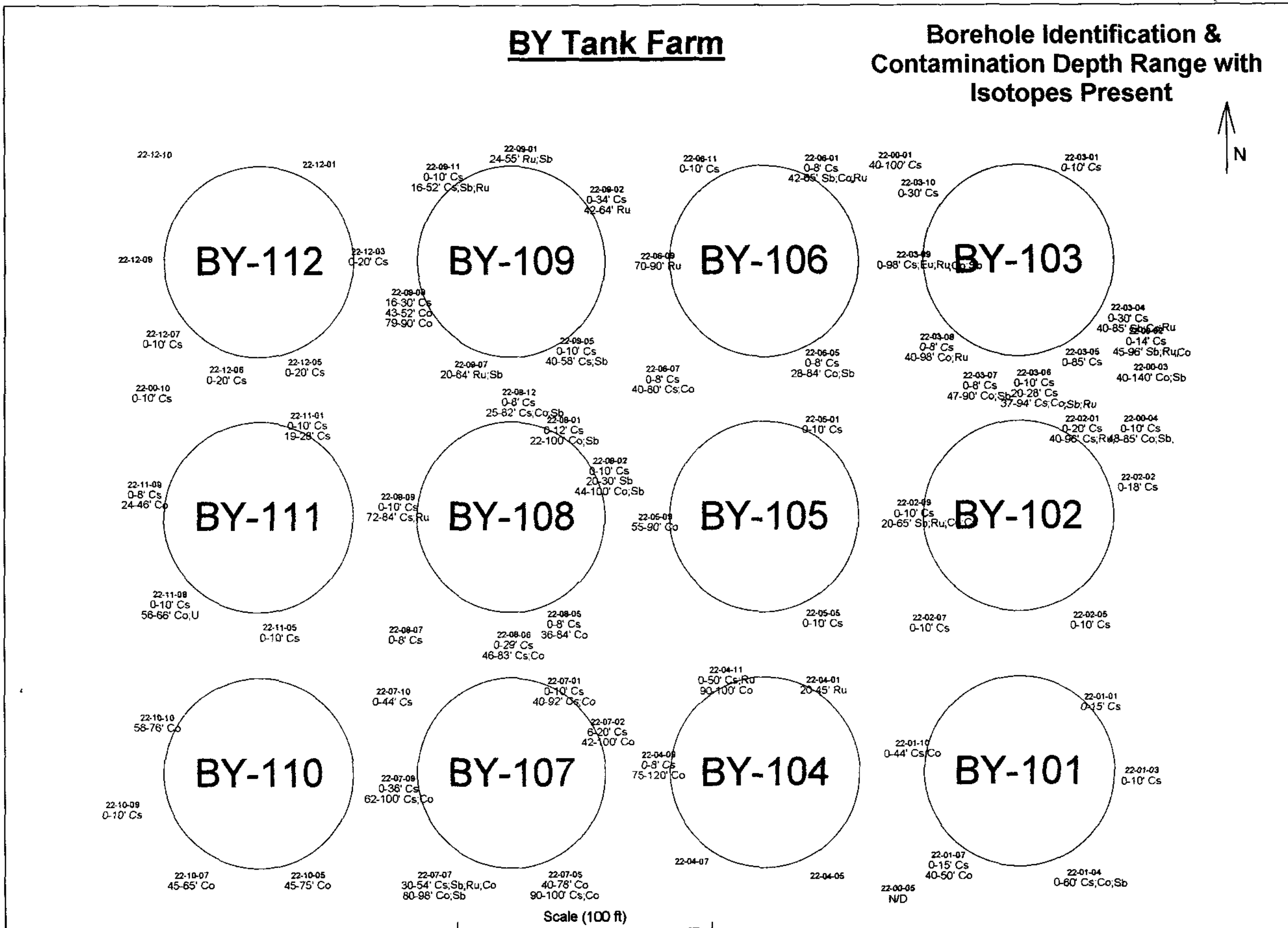


Figure 6. BY Tank Farm Depth Range of Contamination with Isotopes

BY Tank Farm

Borehole Identification & GTP > 10,000 ft*c/s

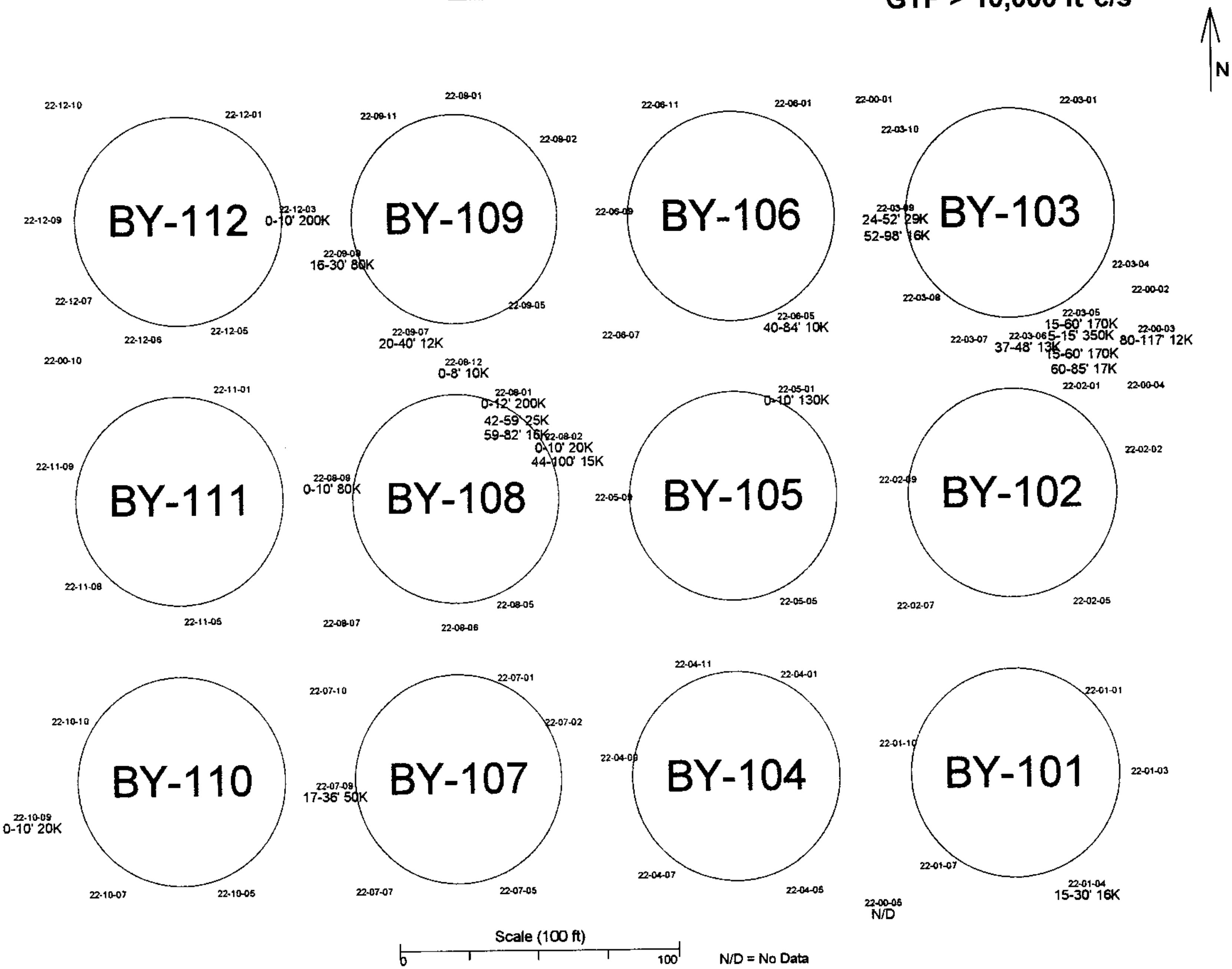


Figure 7. BY Tank Farm Plot of GTP > 10,000 ft*c/s

BY-GTP-10K.jnb

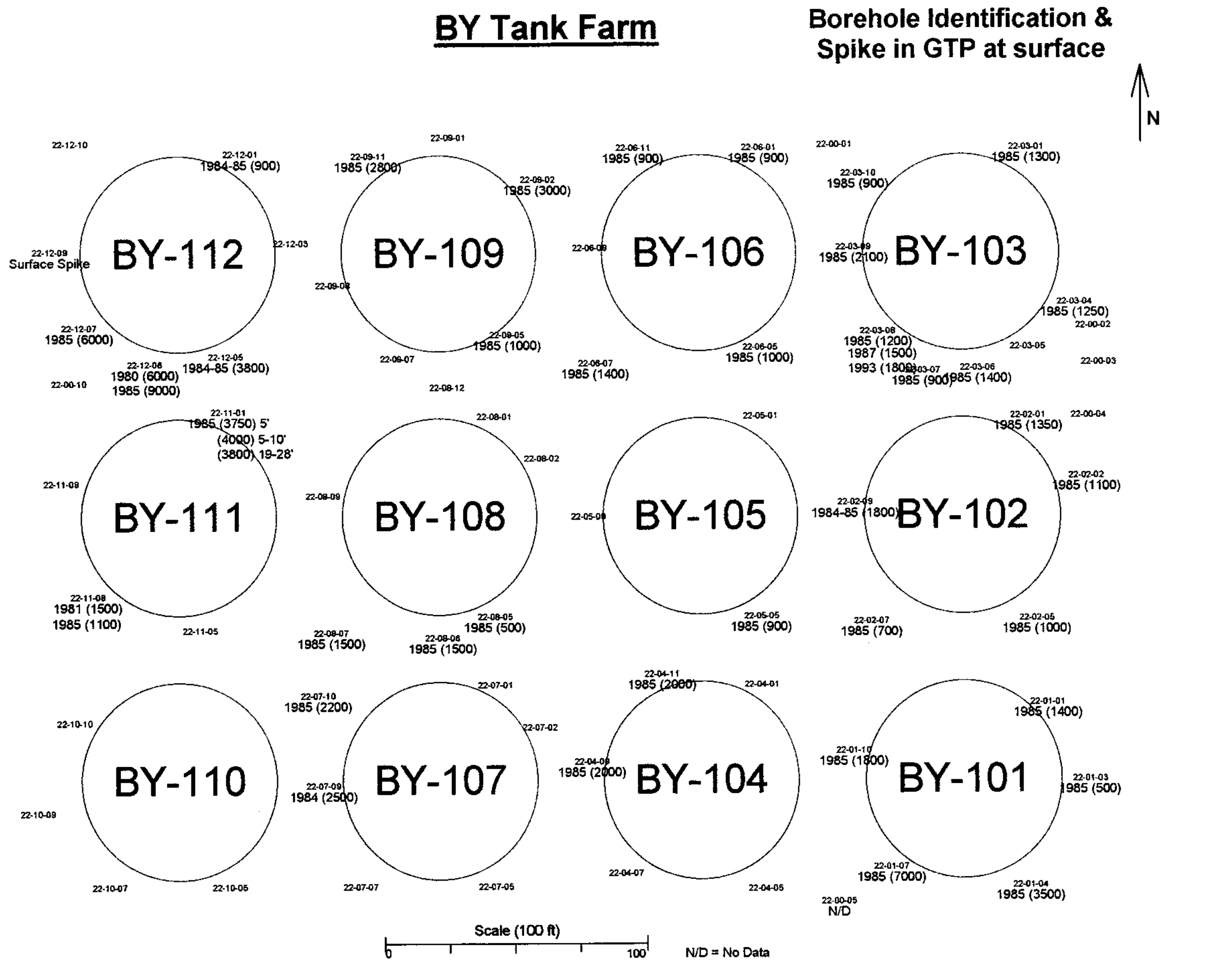


Figure 8. BY Tank Farm Spike in GTP at Surface

Borehole 22-00-01

Contamination (Cs-137) from 40-65 feet appears Stable
Contamination (Cs-137) from 70-84 feet appears Stable
Contamination (Cs-137) from 84-100 feet appears Stable

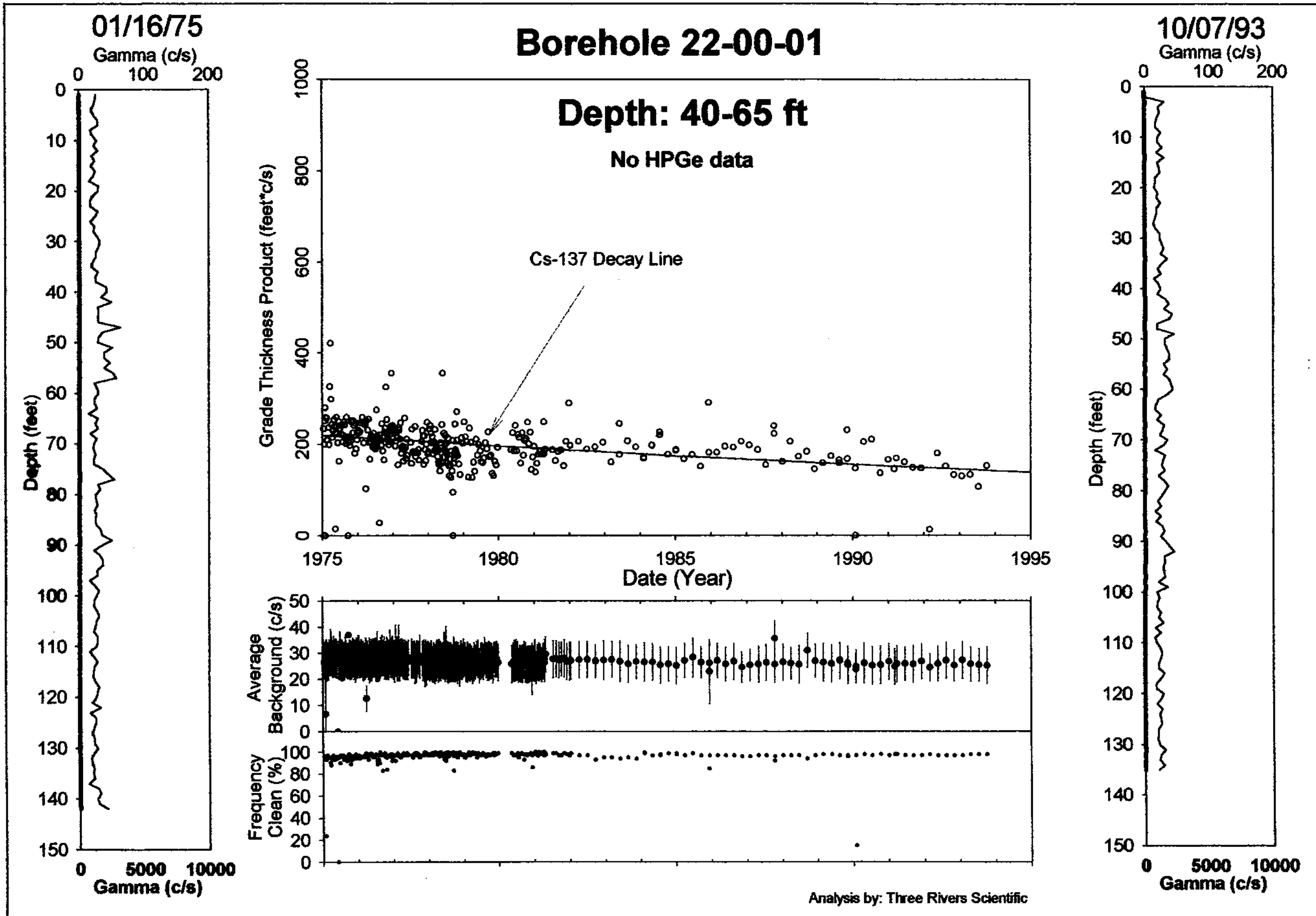
Grade thickness product from 40 to 65, 70 to 84, and 84 to 100 feet is decreasing consistent with Cs-137 (HPGe identified) from 1975 to 1993. Note that the grade thickness product is at low levels for these intervals.

Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	140 ft
Survey Depth :	140 ft
First Survey Date :	1/16/1975
Last Survey Date :	10/7/1993
Number Surveys :	340

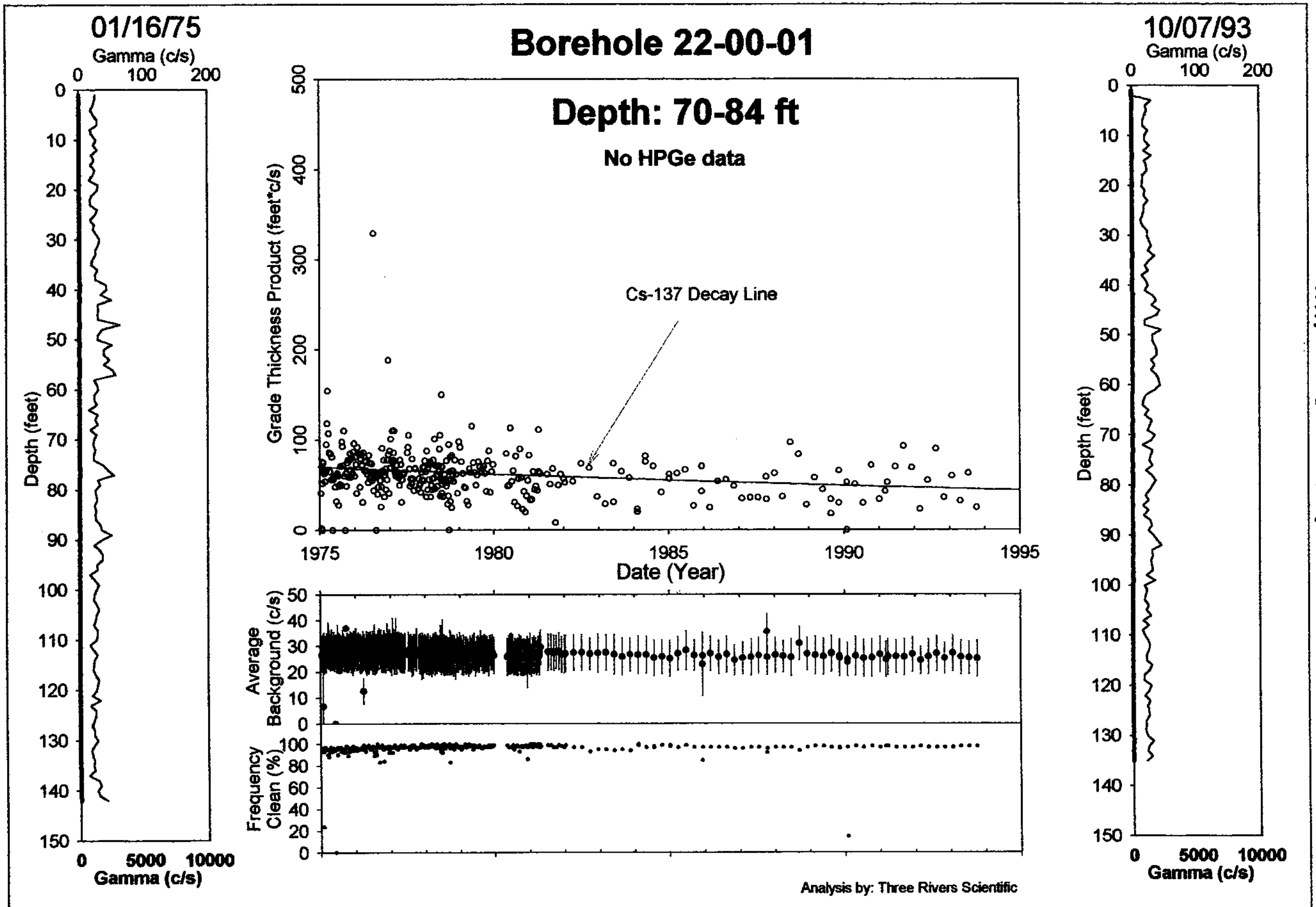
Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	40-65, 70-84, & 84-100 Stable	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	



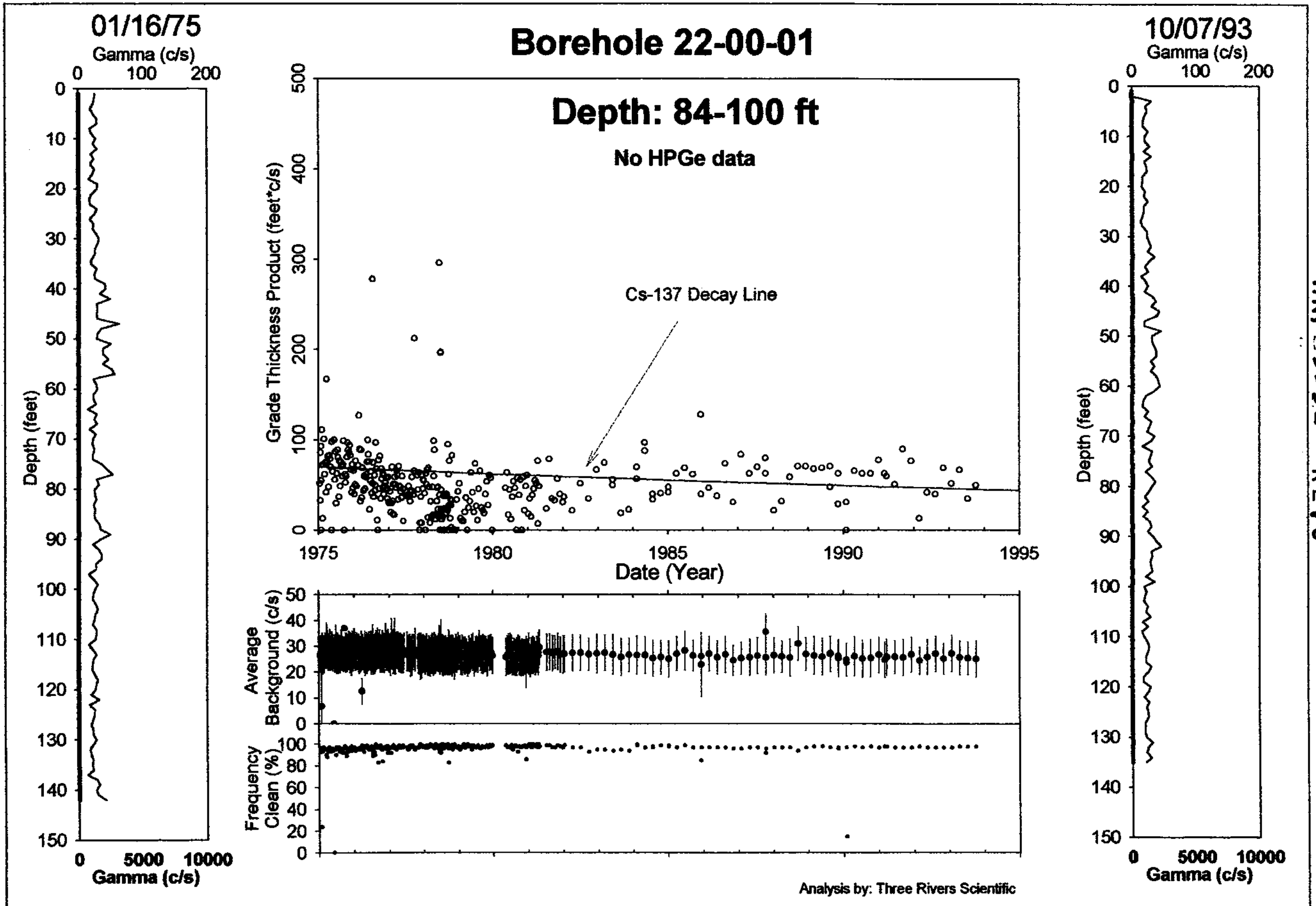
HNF-3532 - REV 0

039



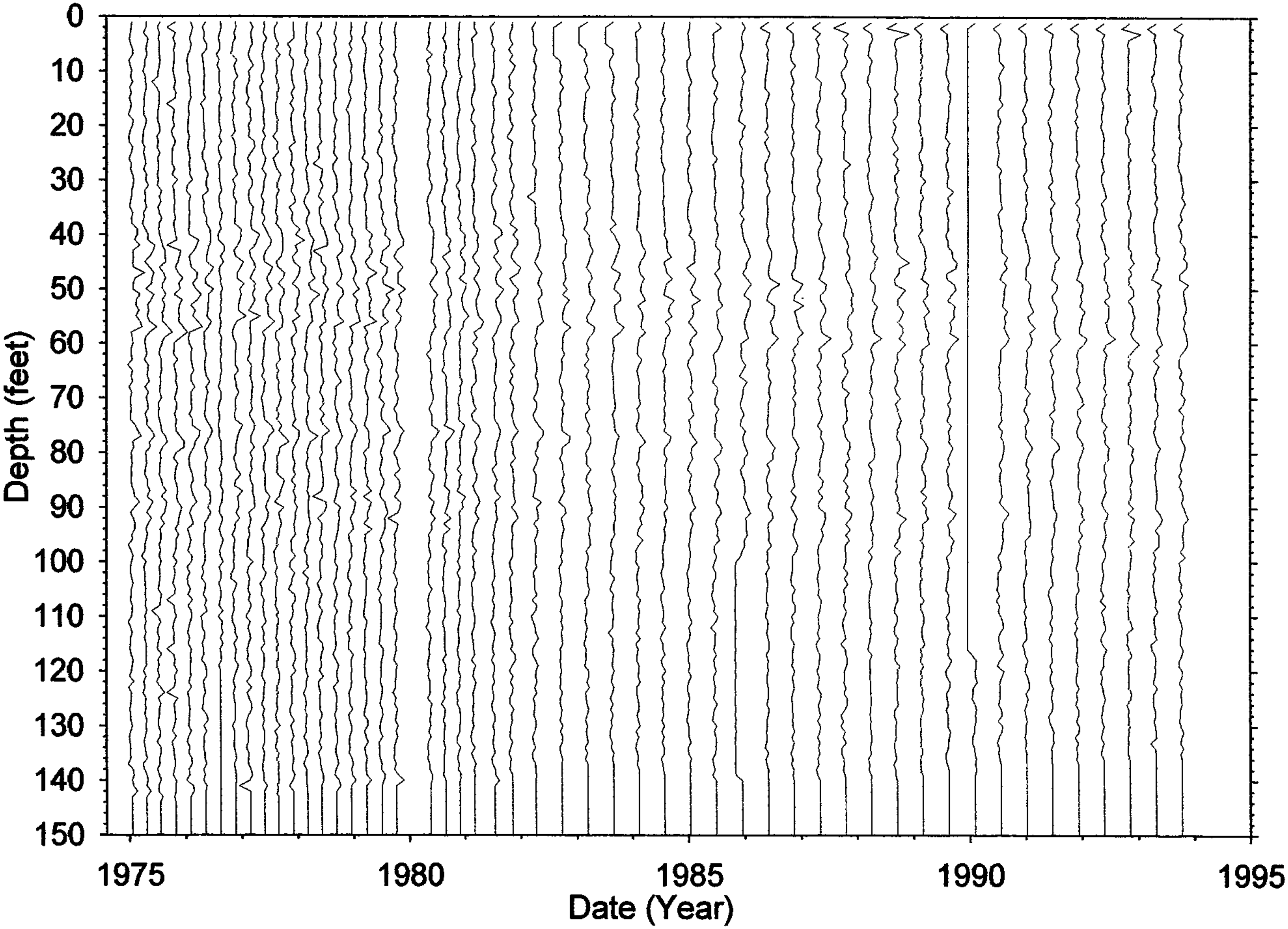
00 040

HNF-3532 -REV0



Borehole 22-00-01
01/16/75
10/07/93
Gamma (c/s)
Depth (feet)
Depth: 84-100 ft
No HPGe data
Cs-137 Decay Line
Grade Thickness Product (feet*c/s)
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

Borehole 22-00-01



HNF-3532 -REV0

Borehole 22-00-02

Contamination (Cs-137) from 0-14 feet is Stable
Contamination (Sb-125) from 45-56 feet is Undetermined
Contamination (Sb-125 & Ru-106) from 56-64 feet is Stable
Contamination (Co-60) from 64-96 feet is UNSTABLE

Grade thickness product from 0 to 14 feet is decreasing consistent with Cs-137 (HPGe identified) from 1975 to 1993.

Grade thickness product from 45 to 56 feet is not decreasing consistent with Sb-125 (HPGe identified), but the deviation cannot be precisely fit to known radionuclide decay rates. Thus the classification is undetermined. Special note, there may be a possibility of downward migration, but well below detection.

Grade thickness product from 56 to 64 feet is decreasing consistent with a least squares fit for Sb-125 (HPGe identified) and Ru-106 (hypothesis) from 1975 to 1993. The least squares fit results in gross gamma contribution ratio of Sb-125 to Ru-106 of 0.72 as of Jan 1975.

Grade thickness product from 64 to 96 feet is not decreasing consistent with Co-60 (HPGe identified). A slower decay rate such as Cs-137 makes an excellent least squares fit, however, there is no indication of Cs-137 and cannot be justified. Downward movement is present at low levels indicated by the stack plot, but the grade thickness product was computed over the entire depth interval in order to conserve downward spreading.

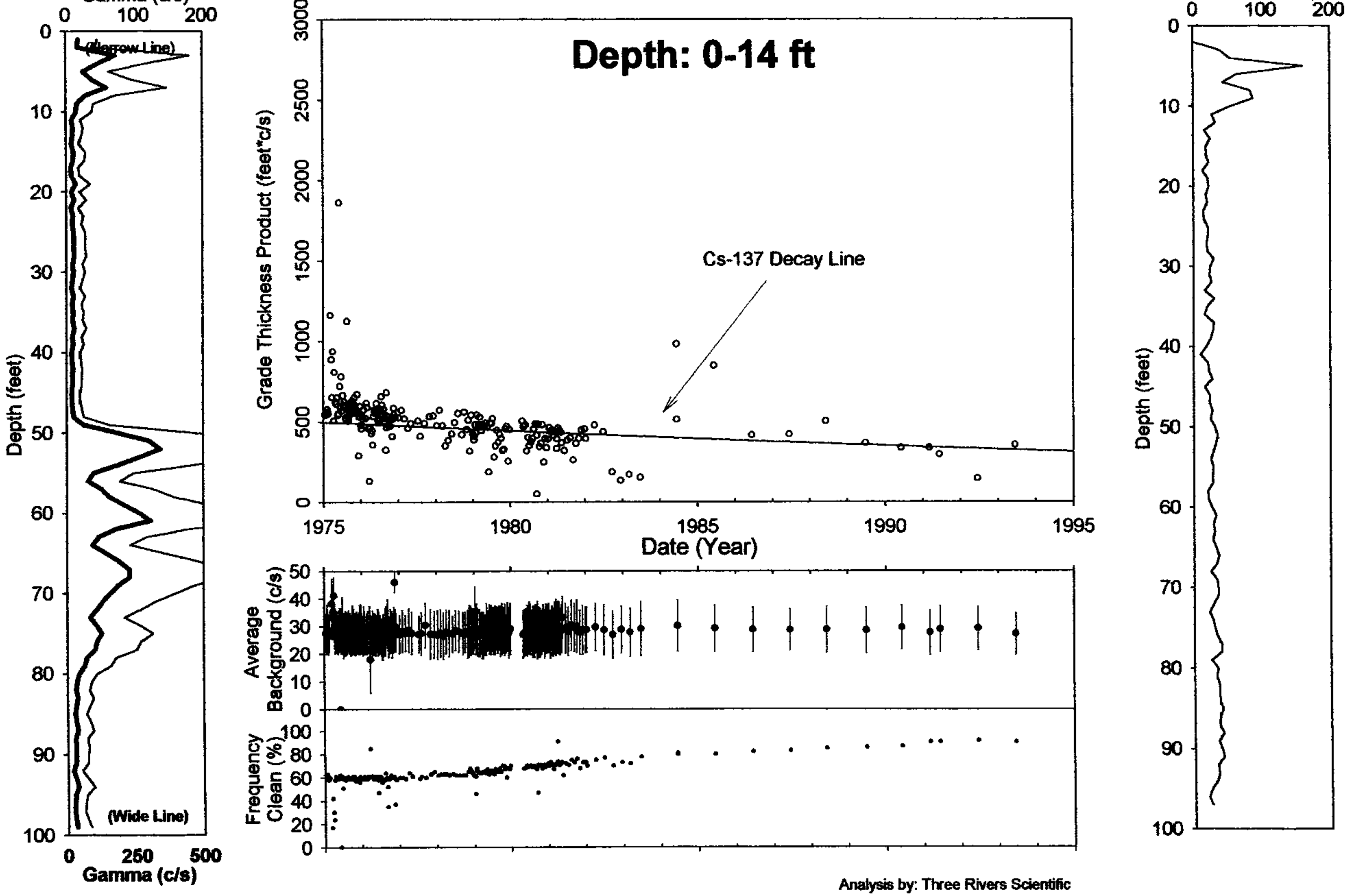
Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/16/1975
Last Survey Date :	6/17/1993
Number Surveys :	206

Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-14 & 56-64 Stable, 45-56 Undetermined 64-96 UNSTABLE	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	

Borehole 22-00-02



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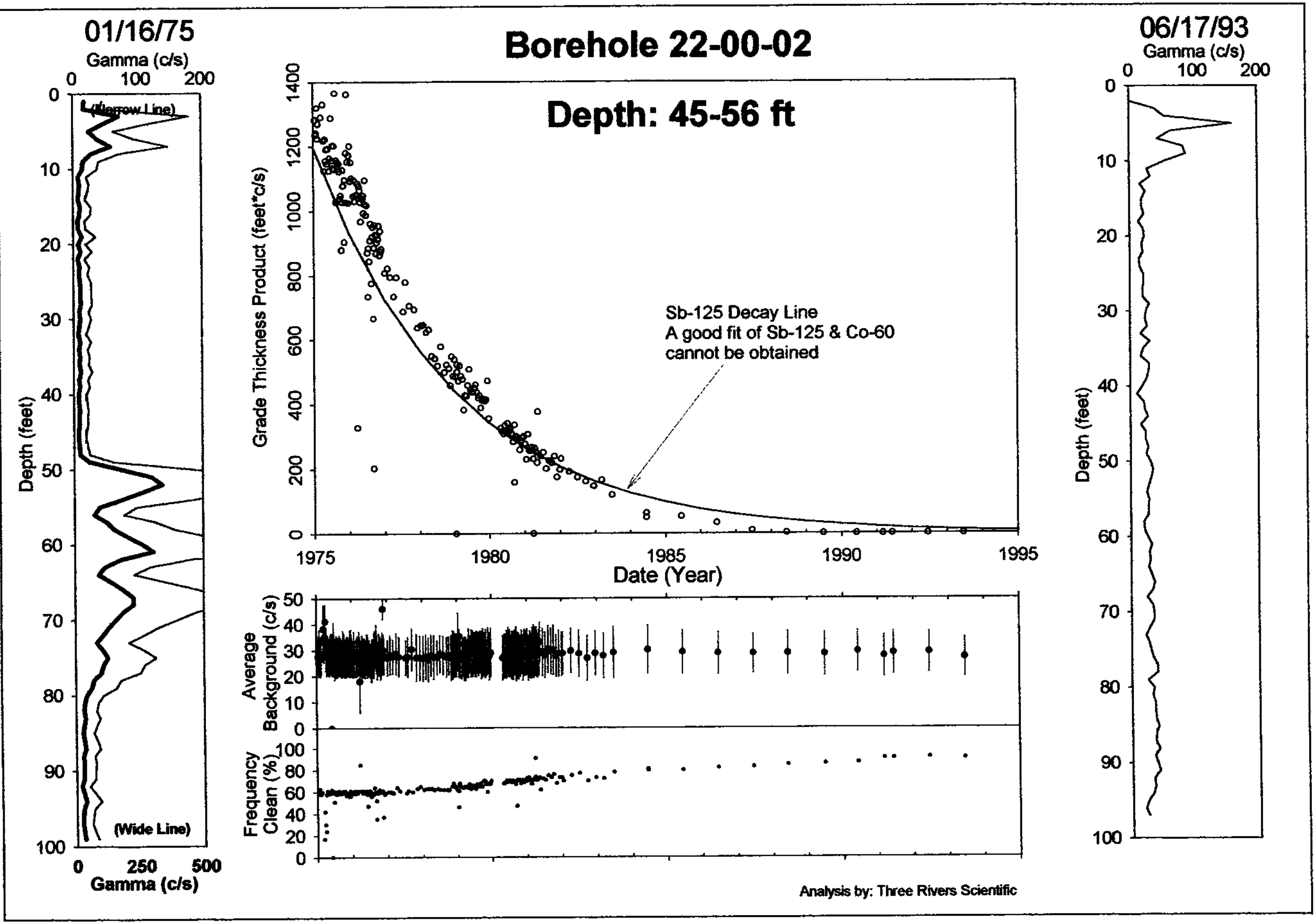
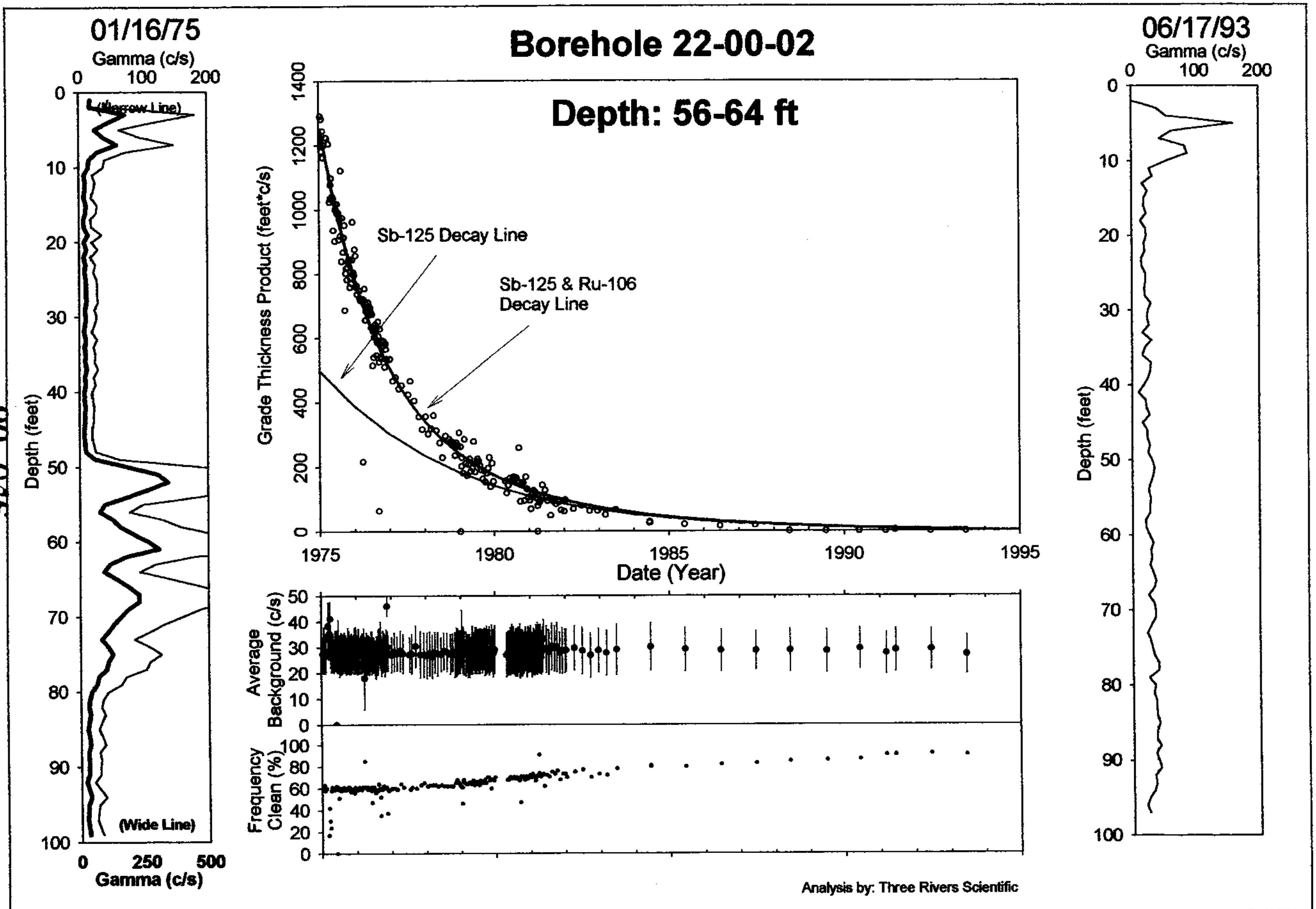
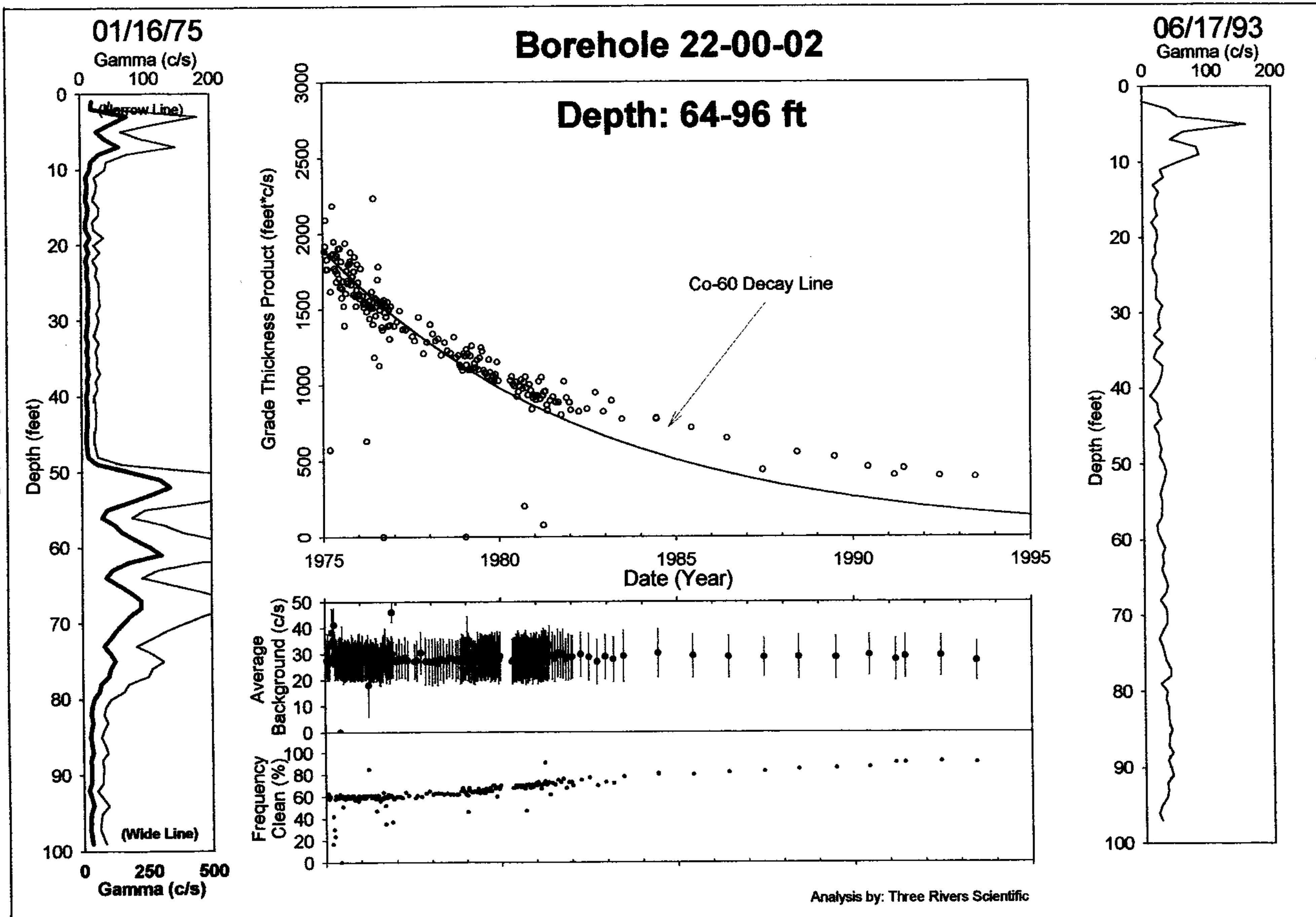


01/16/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Borehole 22-00-02
Depth: 45-56 ft
Grade Thickness Product (feet*c/s)
Sb-125 Decay Line
A good fit of Sb-125 & Co-60
cannot be obtained
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
06/17/93
Gamma (c/s)
Depth (feet)

Borehole 22-00-02



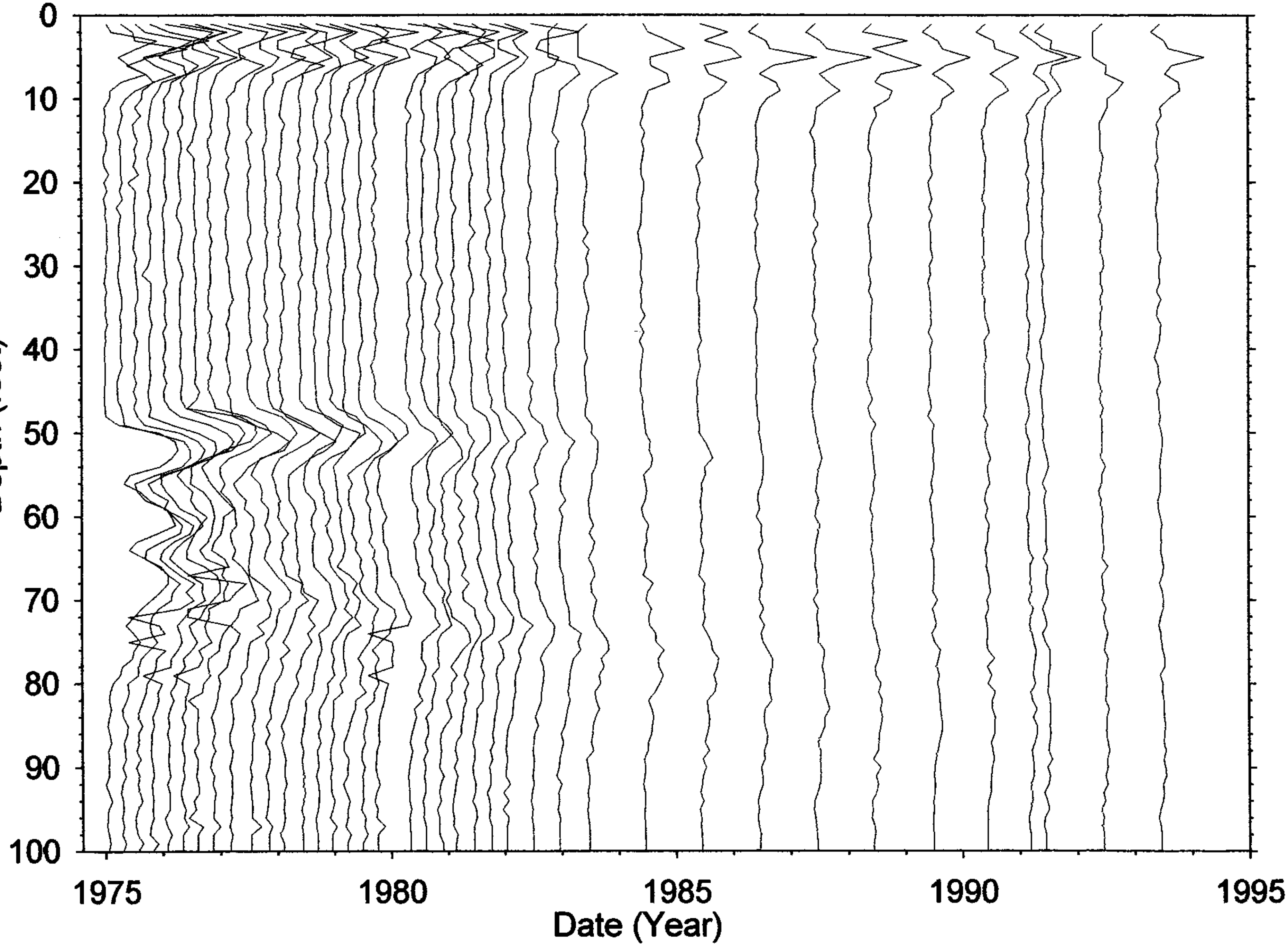
Analysis by: Three Rivers Scientific



01/16/75
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
(Wide Line)
0 250 500
Gamma (c/s)
Borehole 22-00-02
Depth: 64-96 ft
Grade Thickness Product (feet*c/s)
0 500 1000 1500 2000 2500 3000
Co-60 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
06/17/93
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100

00 047

Borehole 22-00-02



Borehole 22-00-03

Contamination (Co-60 & Sb-125) from 40-80 feet is Stable
Contamination (Co-60) from 80-117 feet is UNSTABLE Early
Contamination (Cs-60) from 117-128 feet is Stable
Contamination (Co-60 & Sb-125) from 128-140 feet is Stable

Grade thickness product from 40 to 80 feet is decreasing consistent with Co-60 & Sb-125 (both HPGe identified) from 1975 to 1993. The least squares fit results in gross gamma contribution ratio of Sb-125 to Co-60 of 0.11 as of June 1993.

Grade thickness product from 80 to 117 feet is decreasing consistent with Co-60 (HPGe identified) from 1976 to 1993. However, from 1975 to 1976 there is a rapid decrease in the grade thickness product in excess of Co-60 decay.

Grade thickness product from 117 to 128 feet is decreasing consistent with Co-60 (HPGe identified) from 1975 to 1993.

Grade thickness product from 128 to 140 feet is decreasing consistent with Co-60 (HPGe identified) & Sb-125 (hypothesis) from 1975 to 1993. The least squares fit results in gross gamma contribution ratio of Sb-125 to Co-60 of 0.22 as of June 1993.

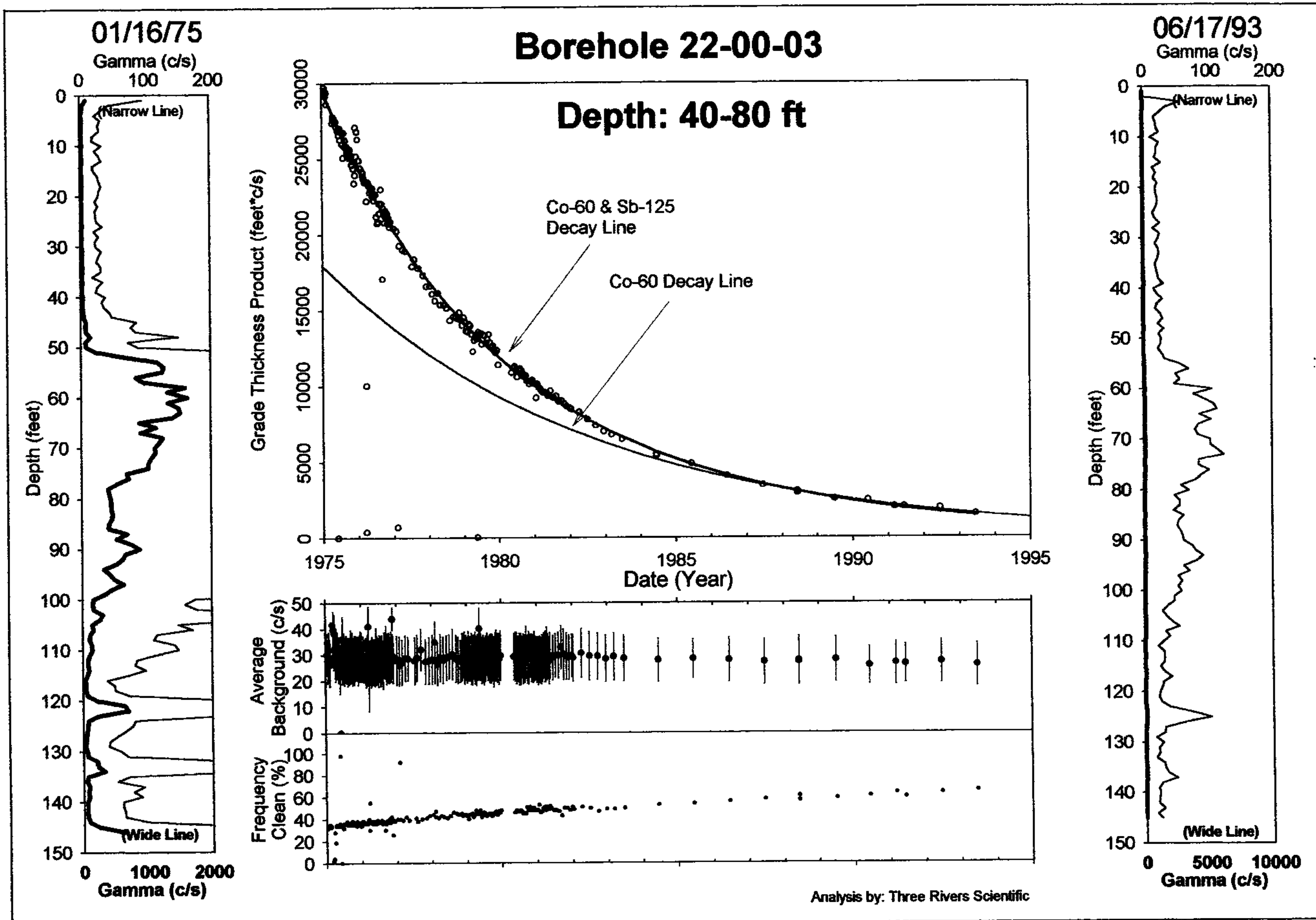
Special note, Cs-137 is also HPGe identified, but not at high enough levels to register with gross gamma for both intervals at 40-80 & 80-117 feet.

Gross Gamma Survey Information

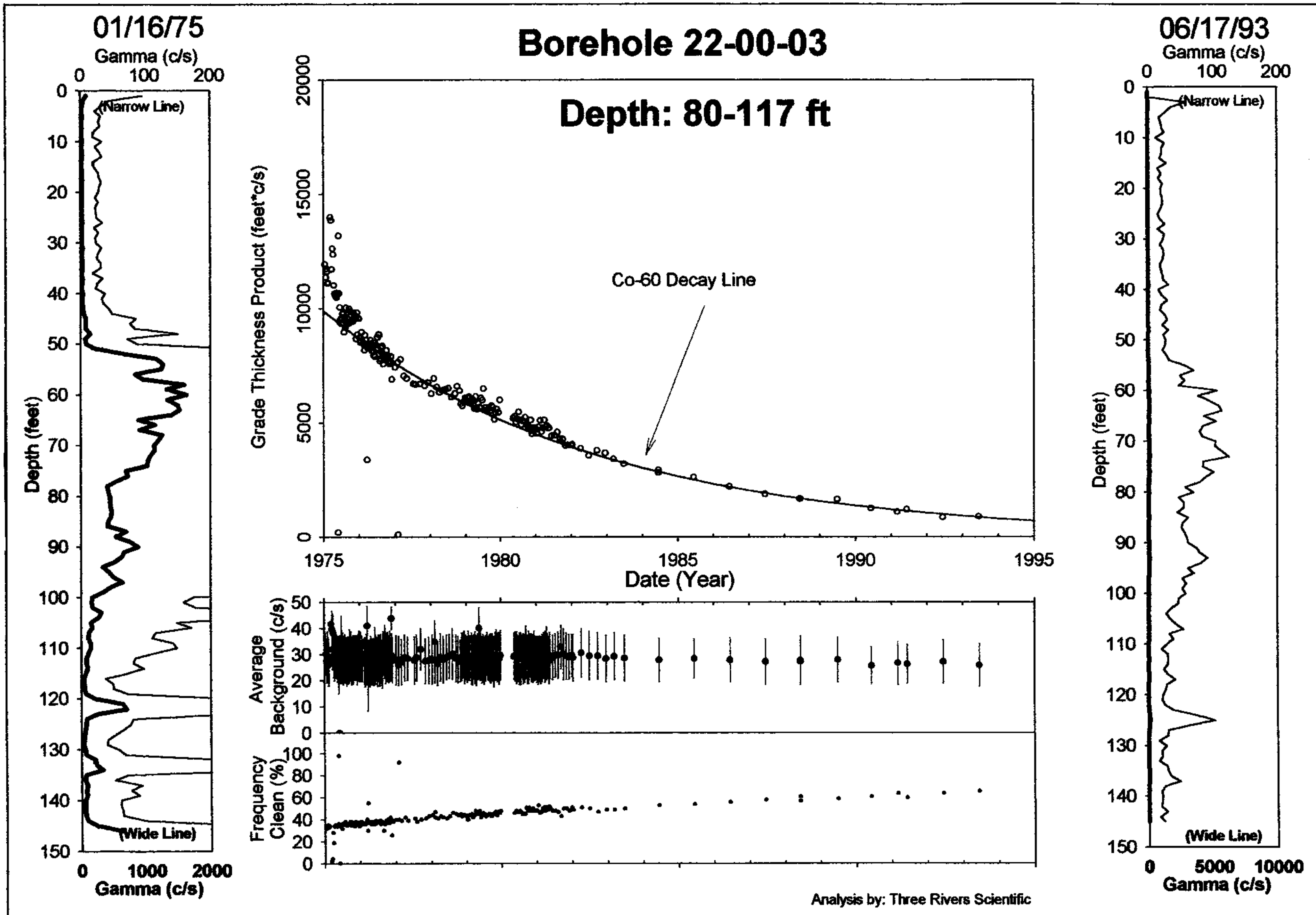
Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	145 ft
Survey Depth :	145 ft
First Survey Date :	1/16/1975
Last Survey Date :	6/17/1993
Number Surveys :	208

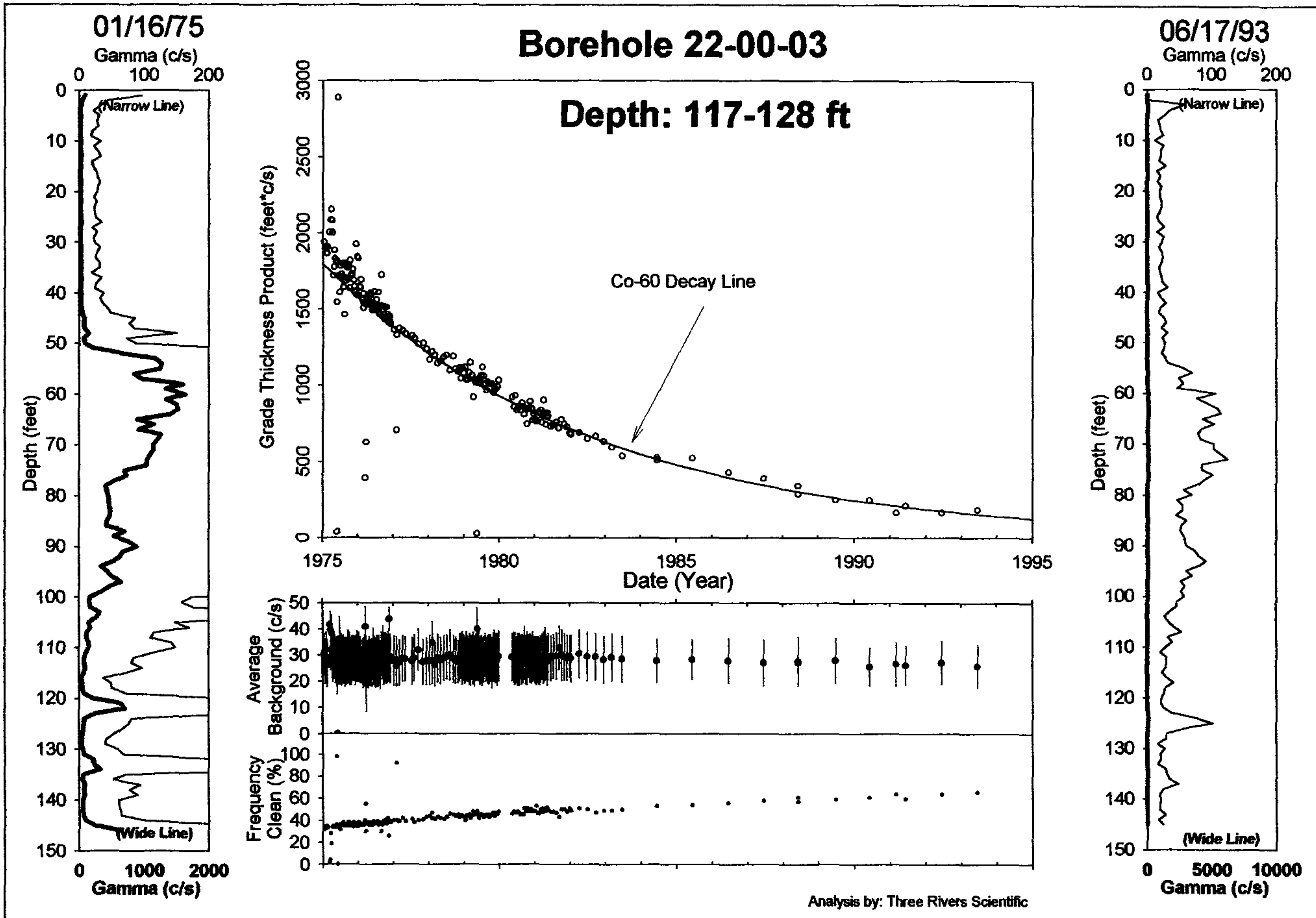
Analysis Notes

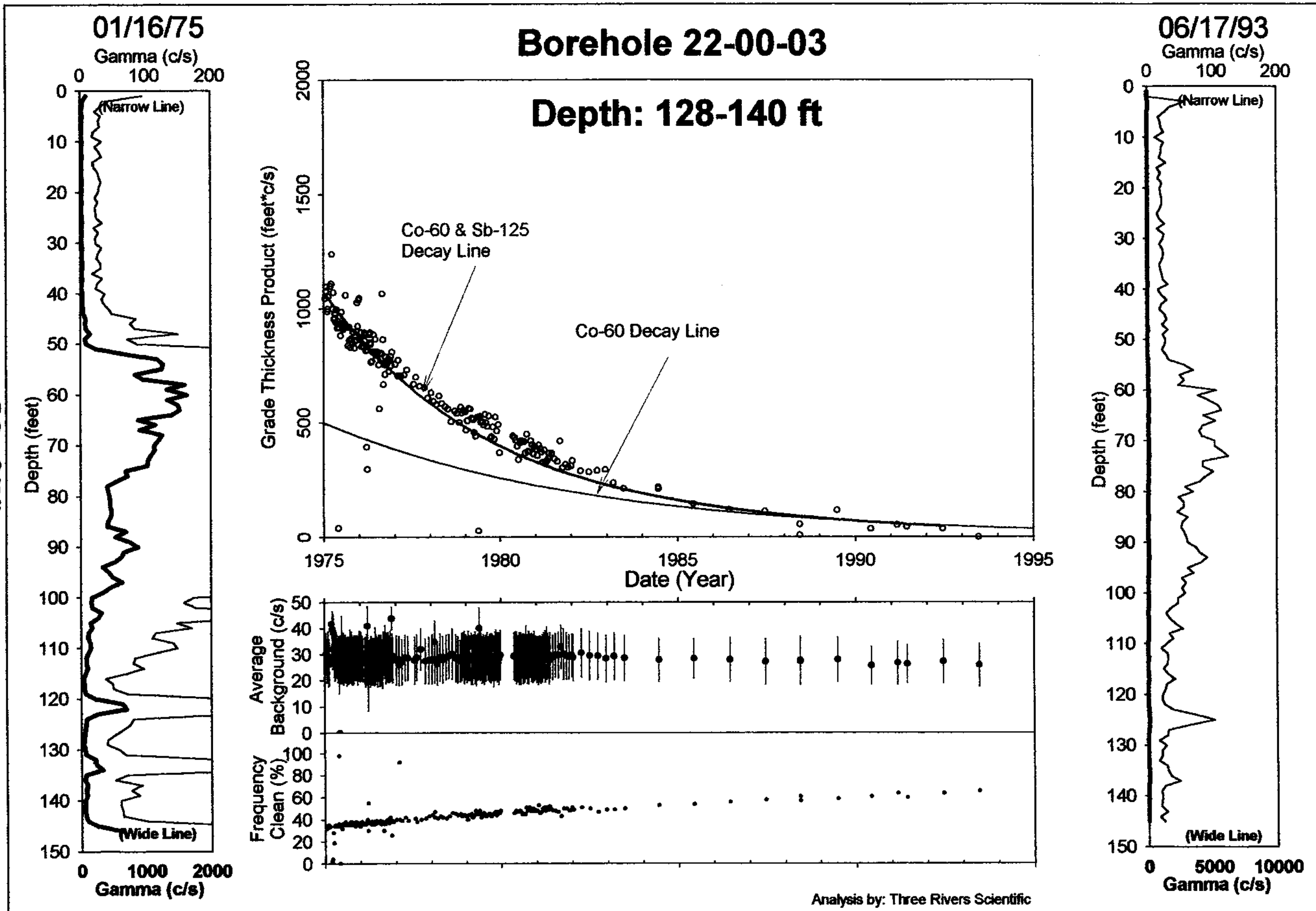
Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	40-80, 117-128, & 128-140 Stable 80-117 UNSTABLE EARLY	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	


Borehole 22-00-03
Depth: 40-80 ft
01/16/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Co-60 & Sb-125
Decay Line
Co-60 Decay Line
Date (Year)
Average
Background (c/s)
Frequency
Clean (%)
06/17/93
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Analysis by: Three Rivers Scientific

Borehole 22-00-03



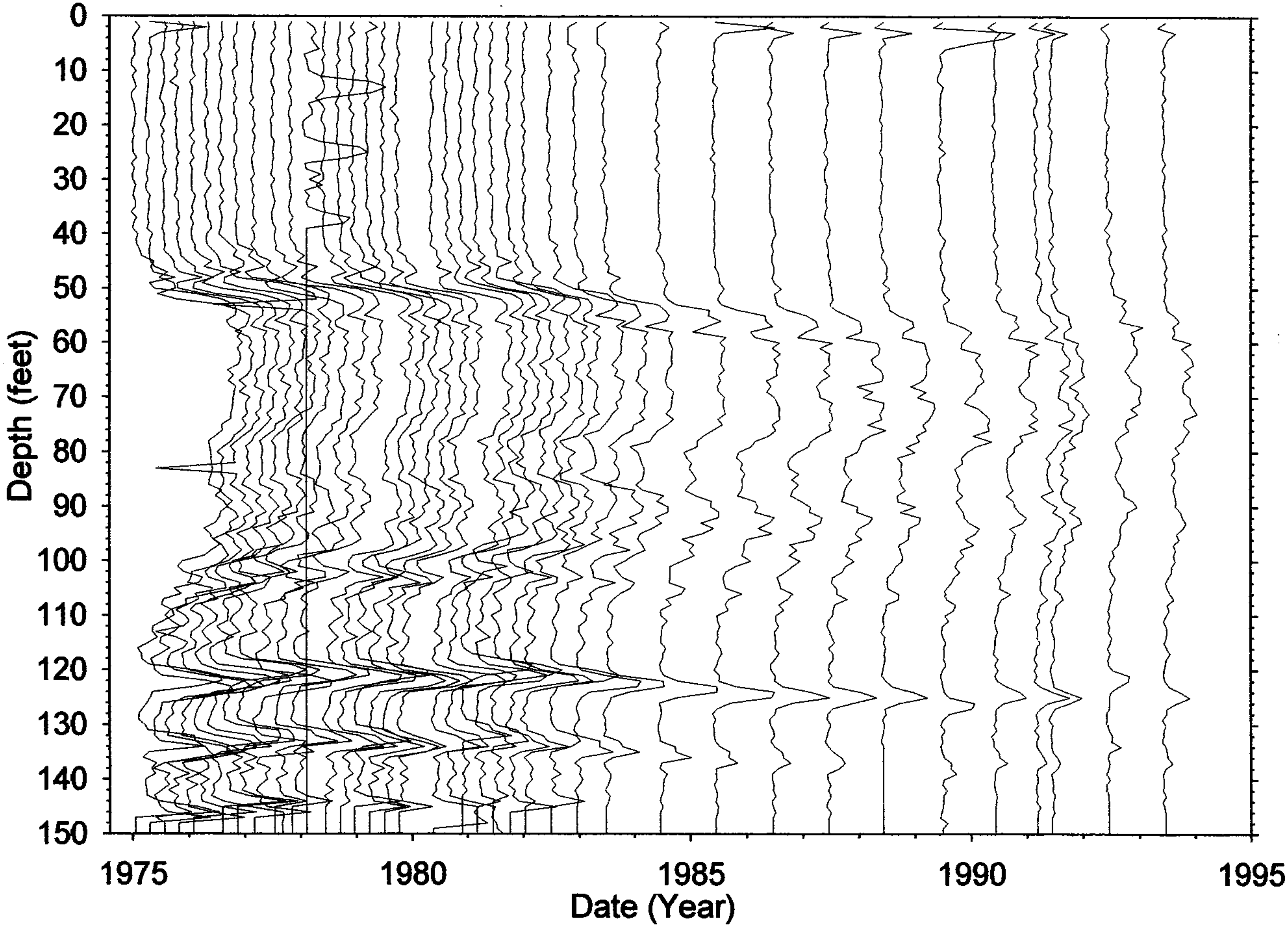

01/16/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Borehole 22-00-03
Depth: 117-128 ft
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
06/17/93
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)



Borehole 22-00-03
Depth: 128-140 ft
01/16/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Co-60 & Sb-125
Decay Line
Co-60 Decay Line
Date (Year)
Average
Background (c/s)
Frequency
Clean (%)
Analysis by: Three Rivers Scientific
06/17/93
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)

00 053

Borehole 22-00-03



HNF-3532 -REV0

00 054

Borehole 22-00-04

Contamination (Cs-137) from 0-10 feet is Tank Farm Activities
Contamination (Co-60 & Sb-125) from 48-70 feet is Stable
Contamination (Co-60 & Ru-106) from 70-85 feet is Stable

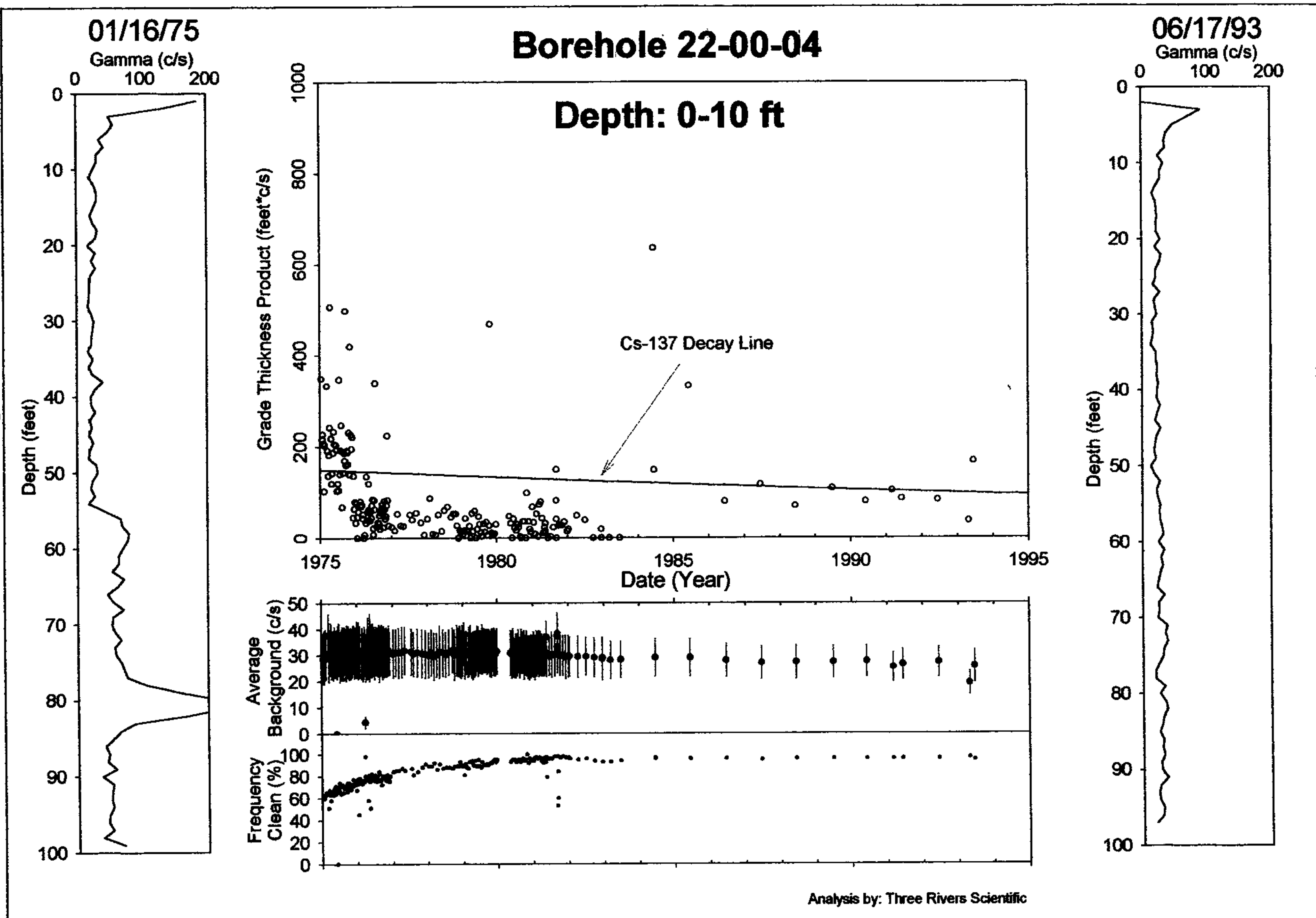
Grade thickness product from 0 to 10 feet is changing erratically indicative of tank farm activities such as changes in transfer lines.
Grade thickness product from 48 to 70 feet is decreasing consistent with Co-60 (HPGe identified) & Sb-125 (hypothesis) from 1975 to 1993. The least squares fit results in gross gamma contribution ratio of Sb-125 to Co-60 of 3.52 as of June 1993.
Grade thickness product from 70 to 85 feet is decreasing consistent with Co-60 (HPGe identified) & Ru-106 (hypothesis) from 1975 to 1993. The least squares fit results in gross gamma contribution ratio of Ru-106 to Co-60 of 3.00 as of Jan 1975.

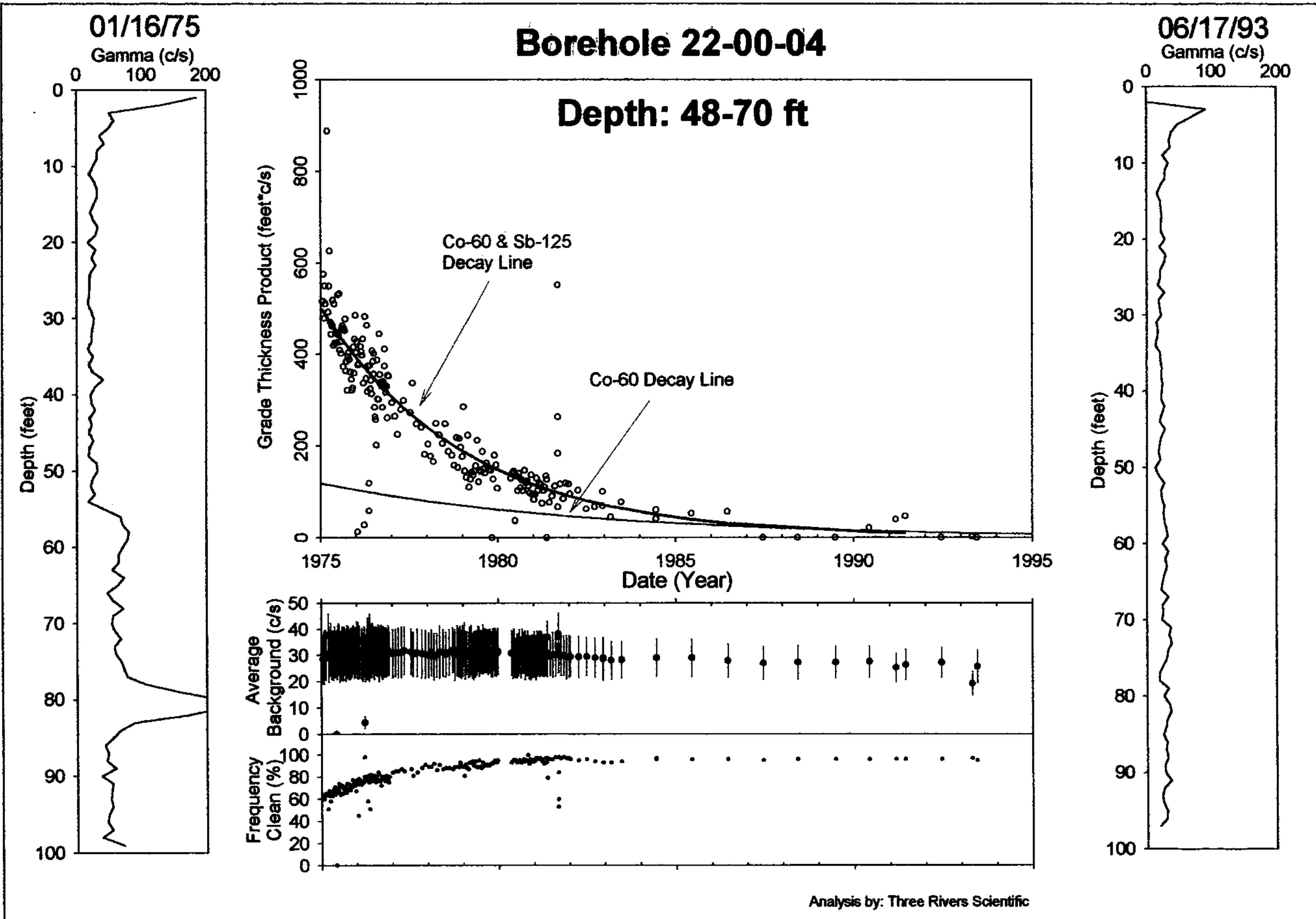
Gross Gamma Survey Information

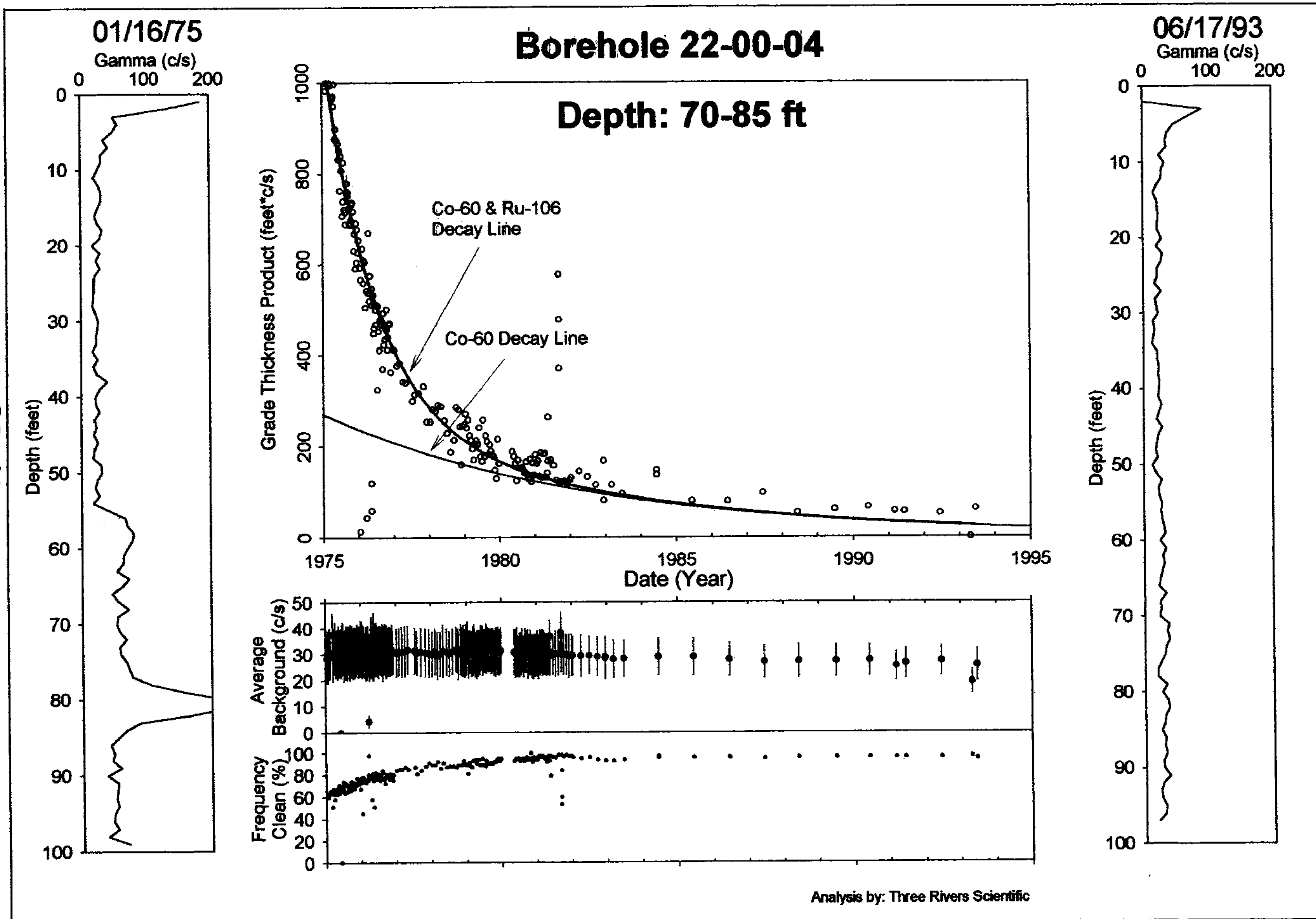
Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/16/1975
Last Survey Date :	6/17/1993
Number Surveys :	210

Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10, 48-70, & 70-85 Stable	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	


Borehole 22-00-04
Depth: 0-10 ft
01/16/75
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
06/17/93
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific

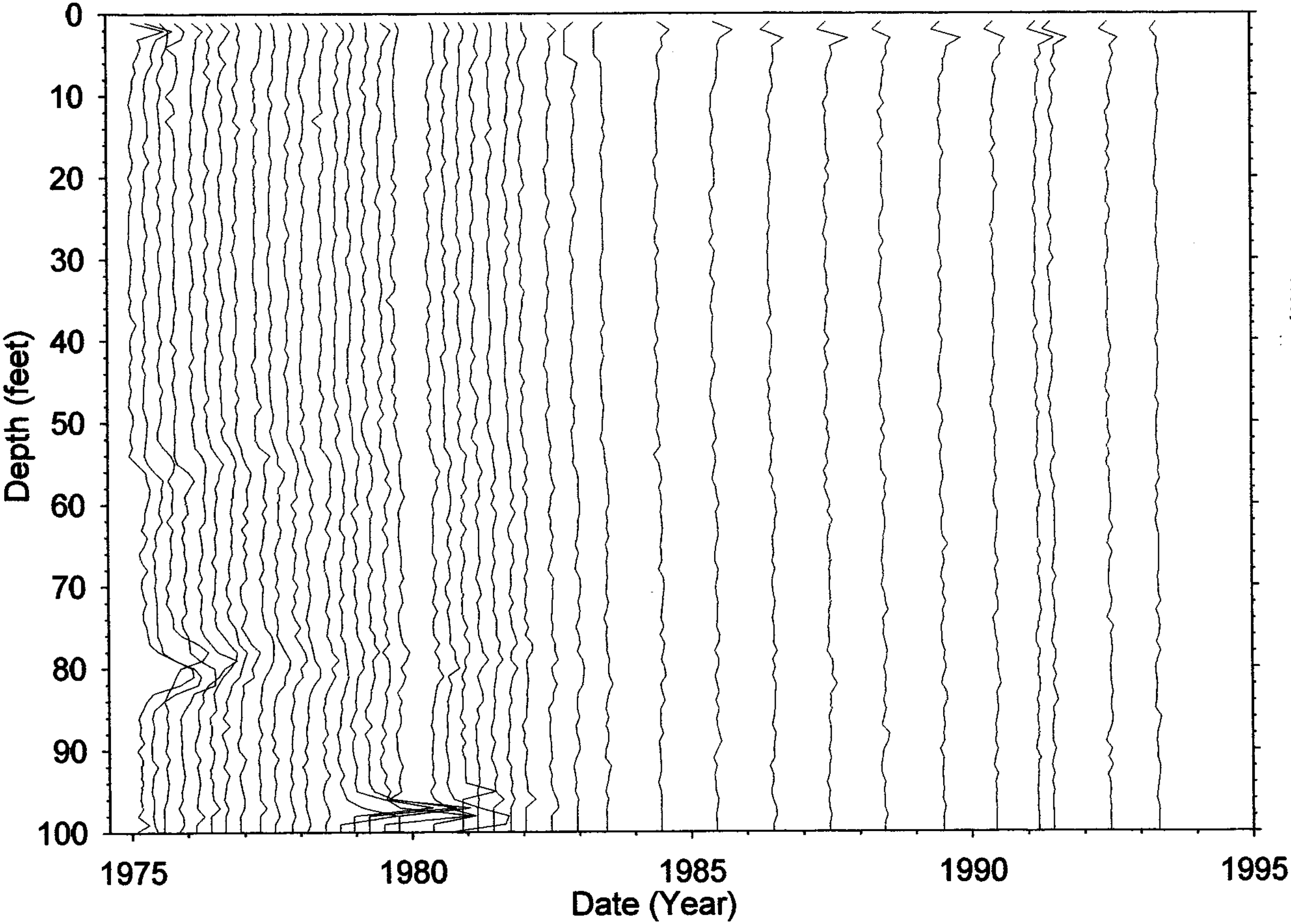

01/16/75
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
Borehole 22-00-04
Depth: 48-70 ft
Grade Thickness Product (feet*c/s)
0 200 400 600 800 1000
Co-60 & Sb-125
Decay Line
Co-60 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average
Background (c/s)
0 10 20 30 40 50
Frequency
Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
06/17/93
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100



01/16/75
Gamma (c/s)
Depth (feet)
Borehole 22-00-04
Depth: 70-85 ft
Grade Thickness Product (feet*c/s)
Co-60 & Ru-106 Decay Line
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
06/17/93
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific

00 058

Borehole 22-00-04



Borehole 22-00-10

Contamination (Cs-137) from 0-10 feet is Tank Farm Activities

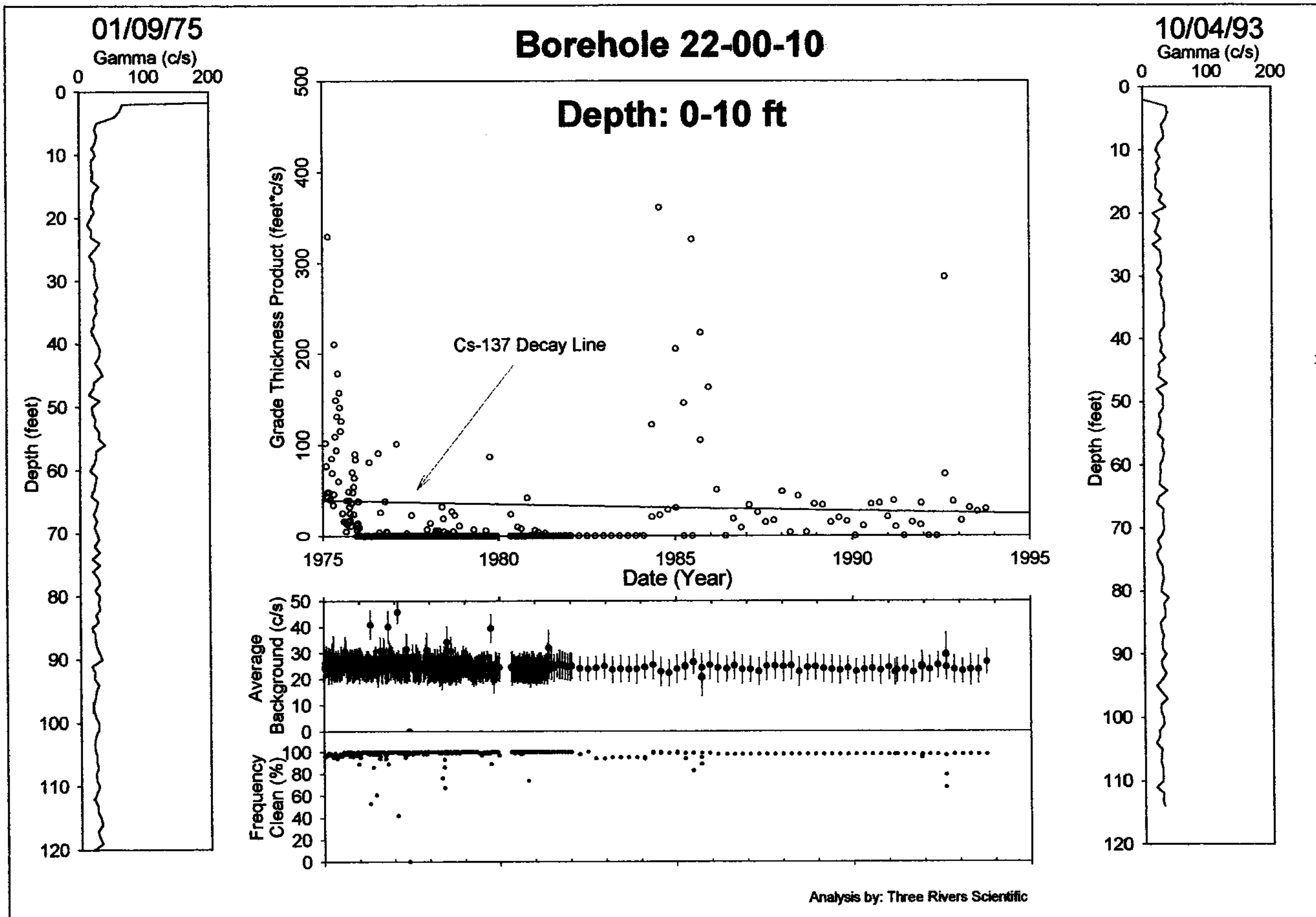
Grade thickness product from 0 to 10 feet is changing erratically indicative of tank farm activities such as changes in transfer lines.
Cs-137 was identified with HPGe detection at 46 feet to levels of 8 pCi/g, which would normally show on the gross gamma log data, but does not, refer to stack plot.

Gross Gamma Survey Information

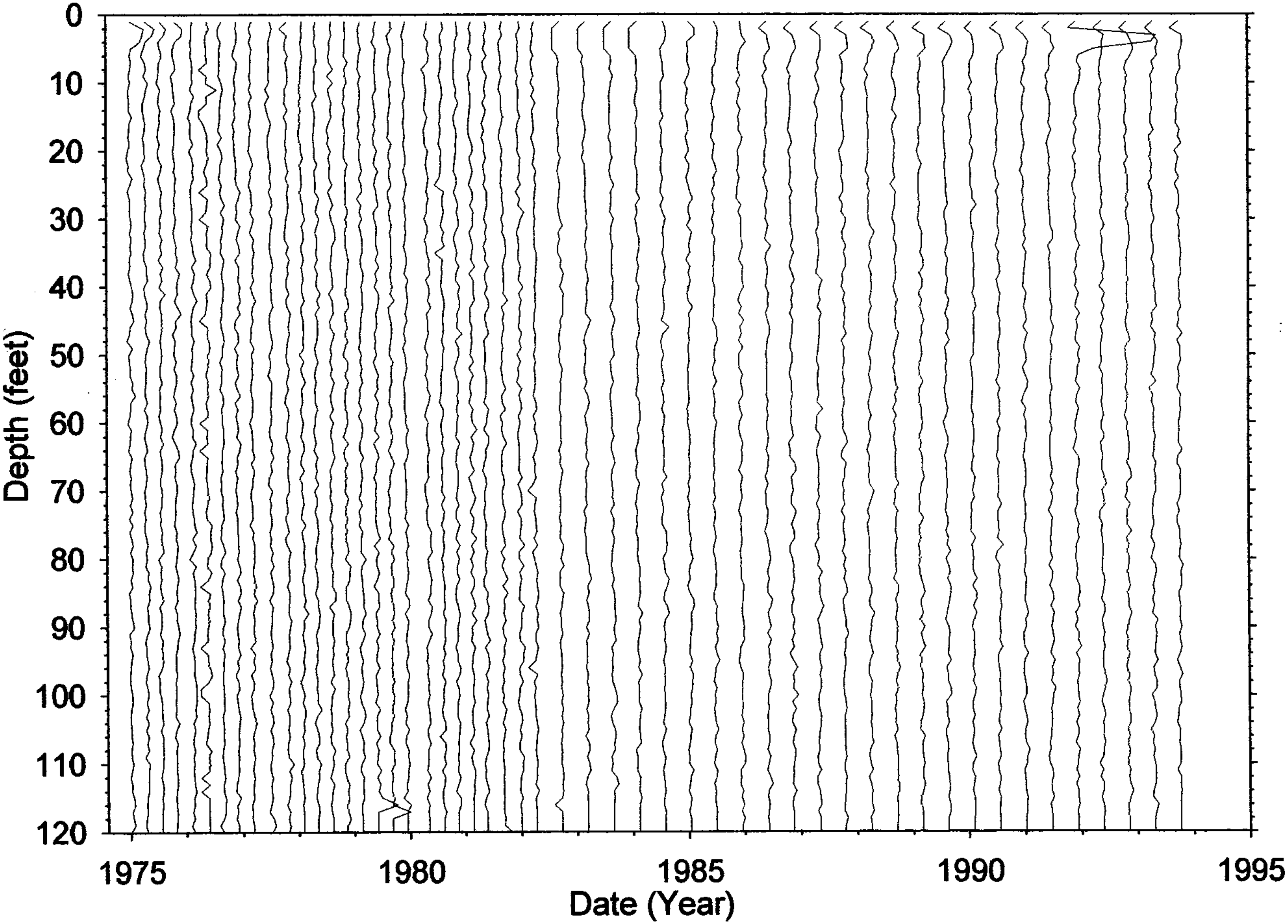
Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	120 ft
Survey Depth :	120 ft
First Survey Date :	1/9/1975
Last Survey Date :	10/4/1993
Number Surveys :	385

Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 Tank Farm Activity	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	


Borehole 22-00-10
Depth: 0-10 ft
01/09/75
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100 110 120
Grade Thickness Product (feet*c/s)
0 100 200 300 400 500
Cs-137 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
10/04/93
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100 110 120
Analysis by: Three Rivers Scientific

Borehole 22-00-10



HNF-3532 -REV0

BY

Dry Well Survey Analysis - Notes

Borehole 22-00-01 Total # Surveys 343 Probe Type D4

\# neutron surveys 3 # GR Surveys 340

Log Date: 1-16-75 1st 10-7-93 Last Presentation Plot Dates ______
(If different from 1st & Last)

Contamination Zone Depth(s): all HI Zones

Isotope from Spectral Survey: not report?

Max Survey Depth 140

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			84 94 100
			Zone from 40-65 70-80 80-93
			92 min in 93 ↳ late 93 ↳ late 93

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Cs apparently for each interval but @ very low levels.

Analyst Name [signature] S/W ver TFGROSS 2.2

BY

Dry Well Survey Analysis - Notes

Borehole 22-00-02 Total # Surveys 211 Probe Type 04

\# neutron surveys 5 # GR Surveys 206

Log Date: 1-16-75 1st 6-17-93 Last Presentation Plot Dates

(If different from 1st & Last)

Contamination Zone Depth(s):

Isotope from Spectral Survey: no report Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment
			56-64 could be Rn + Sb

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg Bkg	Comment

Analysis Notes

From stack 45-56 56-64 64-84 rapid decay

& 0-14 slow decay

No reasonable fits are generated, & believe

downward movement → to 90' ∴ Try 3 comp fit

for 45-95 & ew!

Analyst Name [signature]

S/W ver TFGRASS 2.2

filein := "two45-56.txt" **Well 21-00-02**

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

N := last(yr) N = 194 i := 0.. N k := 0.. 300 j := 0.. 299 τeu := 5.27

<u>Eu variables are Co-60</u>

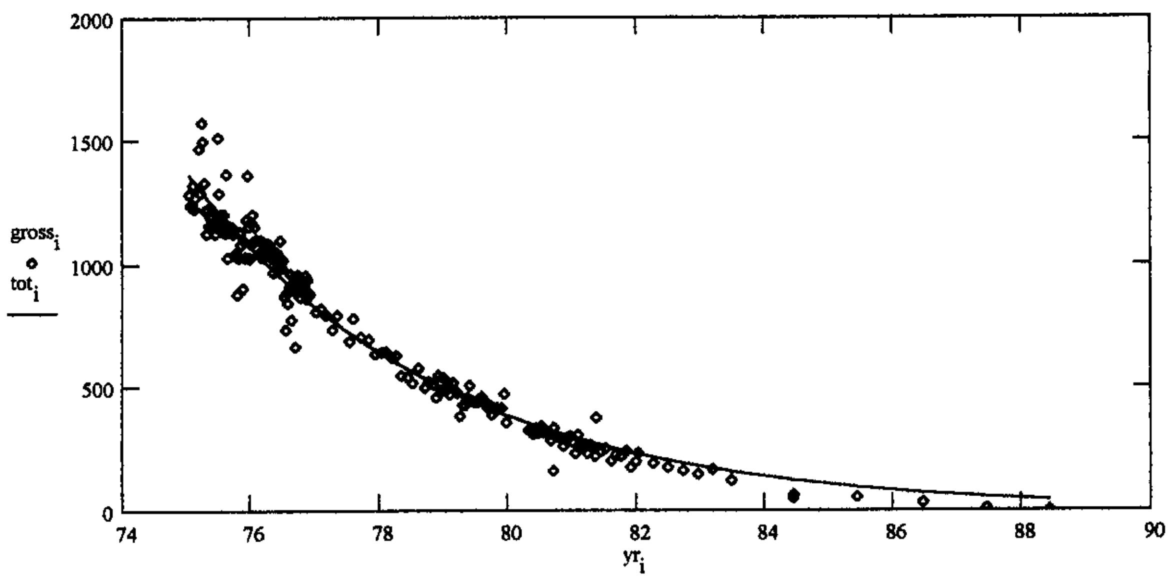
τco := 5.27 τcs := 2.77 aco := 00 acs := 1415 aeu := -38

$$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \qquad Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \qquad Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1 \qquad tot_i := Cs_i + Eu_i$$

Cs variables are Sb-125

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

ssq(acs, aeu) = 0   1 = 1

$$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := Minerr(acs, aeu)$$

$\alpha cs = 1.425 \cdot 10^3$ Sb-125 $\alpha eu = -46.978$ Co-60

$$\frac{\alpha cs}{\alpha eu} = -30.338$$

$$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \qquad Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \qquad tot_i := Cs_i + Eu_i$$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop.txt") := out

$$\frac{Eu_N}{Cs_N} = -0.162$$

Unreasonable fit

filein := "two56-64.txt" **Well 21-00-02**

A := READPRN(filein) $yr := A^{\langle 1 \rangle}$ $net := A^{\langle 7 \rangle}$ $bkg := A^{\langle 6 \rangle}$ $max := A^{\langle 4 \rangle}$

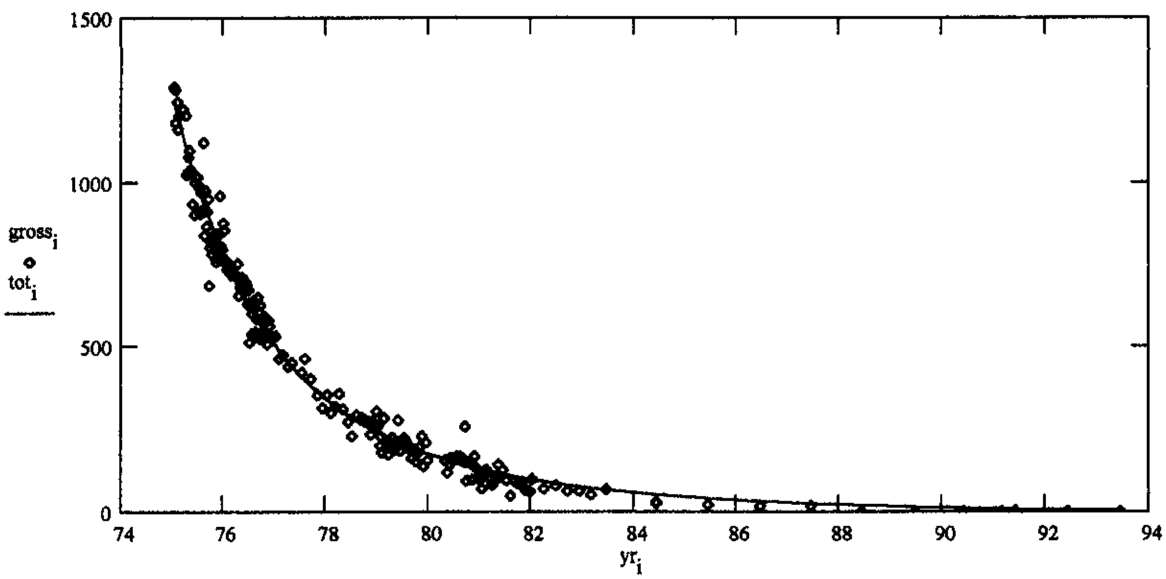
N := last(yr) N = 198 i := 0 .. N k := 0 .. 300 j := 0 .. 299 $\tau eu := 1$

$\tau co := 5.27$ $\tau cs := 2.77$ aco := 0 acs := 534 Eu variables are Ru-106 aeu := 744

$$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \qquad Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \qquad Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1 \qquad tot_i := Cs_i + Eu_i$$

$gross_i := net_i$ Cs variables are SAb-125

This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + \left[a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right] \right]^2$$

Given

ssq(acs, aeu) = 0 1 = 1

$$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := Minerr(acs, aeu)$$

$\alpha cs = 534$ $\alpha eu = 744$

Sb-125 Ru-106

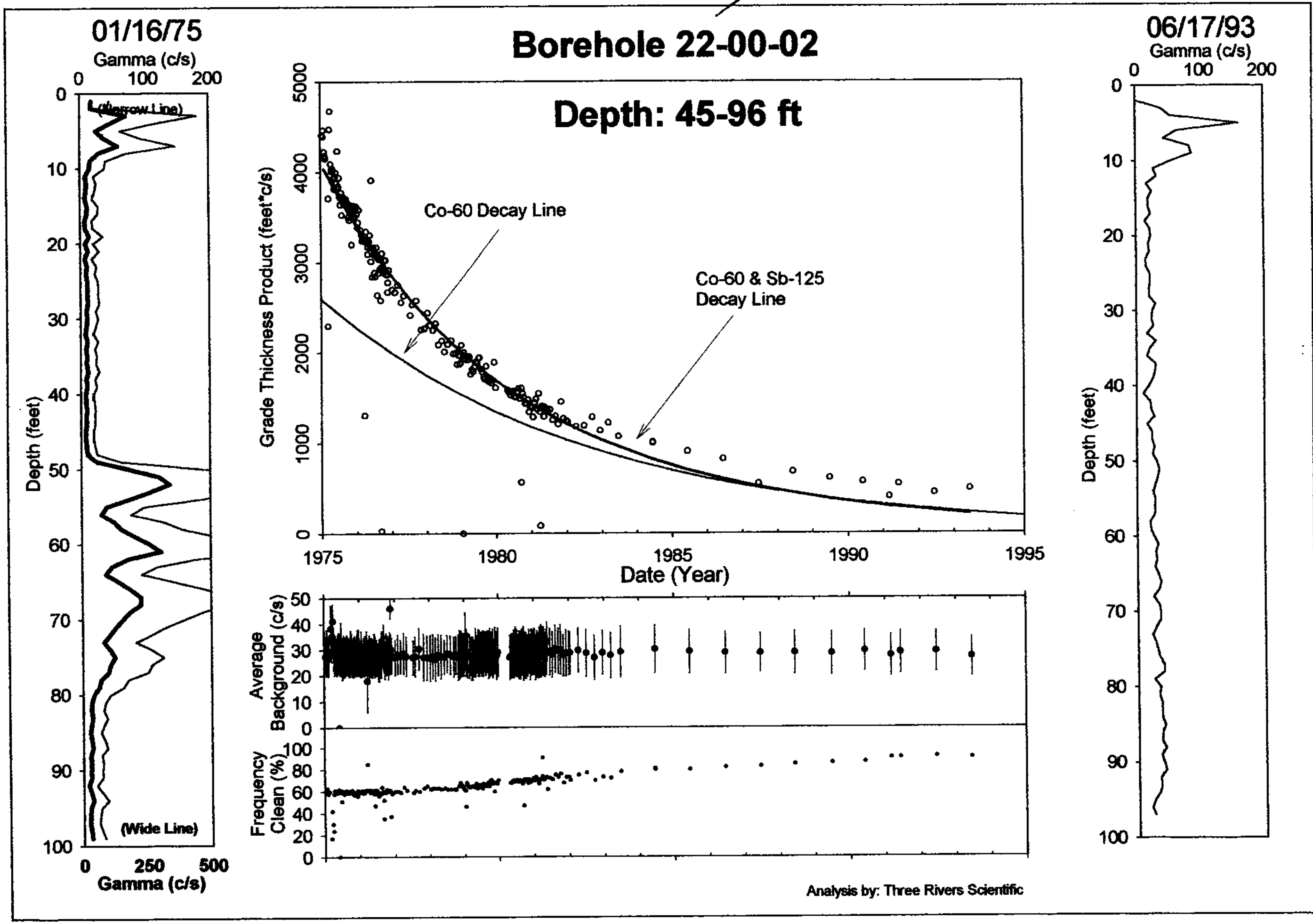
$$\frac{\alpha cs}{\alpha eu} = 0.718$$

$$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \qquad Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$$

$tot_i := Cs_i + Eu_i$

$out^{\langle 0 \rangle} := yr$ $out^{\langle 1 \rangle} := tot$ WRITEPRN("twop56-64.txt") := out $\frac{Eu_N}{Cs_N} = 3.915 \cdot 10^{-4}$

Ref. Only



00 067

HNF-3532 -REV0

BY

Dry Well Survey Analysis - Notes

Borehole 22-00-07 Total # Surveys 209 Probe Type 04

\# neutron surveys 1 # GR Surveys 208

Log Date: 1-16-75 1st 6-17-93 Last Presentation Plot Dates ____
(If different from 1st & Last)

Contamination Zone Depth(s): ~~48 ...~~

Isotope from Spectral Survey: no report

Max Survey Depth 145

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment

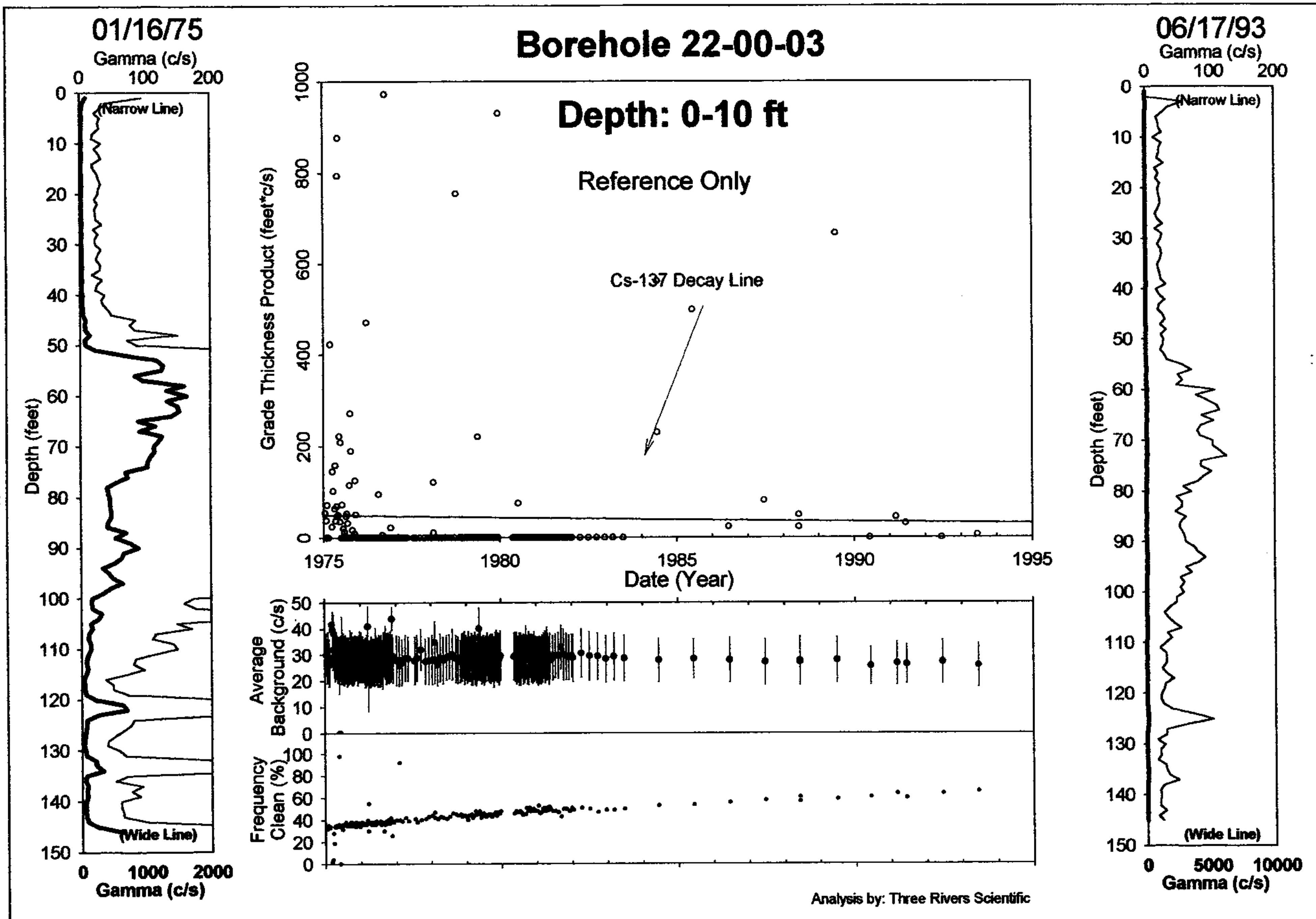
BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

40-50 good fit with Co ± 56
117-128 " / " " Co
128-140 can't automatically (math) get late good fit
but did after better starting values

Analyst Name [signature] S/W ver TFGR PSS 2.2


Borehole 22-00-03
Depth: 0-10 ft
Reference Only
Cs-137 Decay Line
Grade Thickness Product (feet*c/s)
Date (Year)
Average Background (c/s)
Frequency Clean (%)
01/16/75
Gamma (c/s)
Depth (feet)
(Narrow Line)
(Wide Line)
06/17/93
Analysis by: Three Rivers Scientific

filein := "two40-80.txt"

Well 21-00-03

A := READPRN(filein) $\quad yr := A^{<1>} \quad net := A^{<7>} \quad bkg := A^{<6>} \quad max := A^{<4>}$

$N := last(yr) \quad N = 197 \quad i := 0..N \quad k := 0..300 \quad j := 0..299 \quad \tau eu := 2.77$

$\tau co := 5.27 \quad \tau cs := 5.27 \quad aco := 0 \quad acs := 15120$

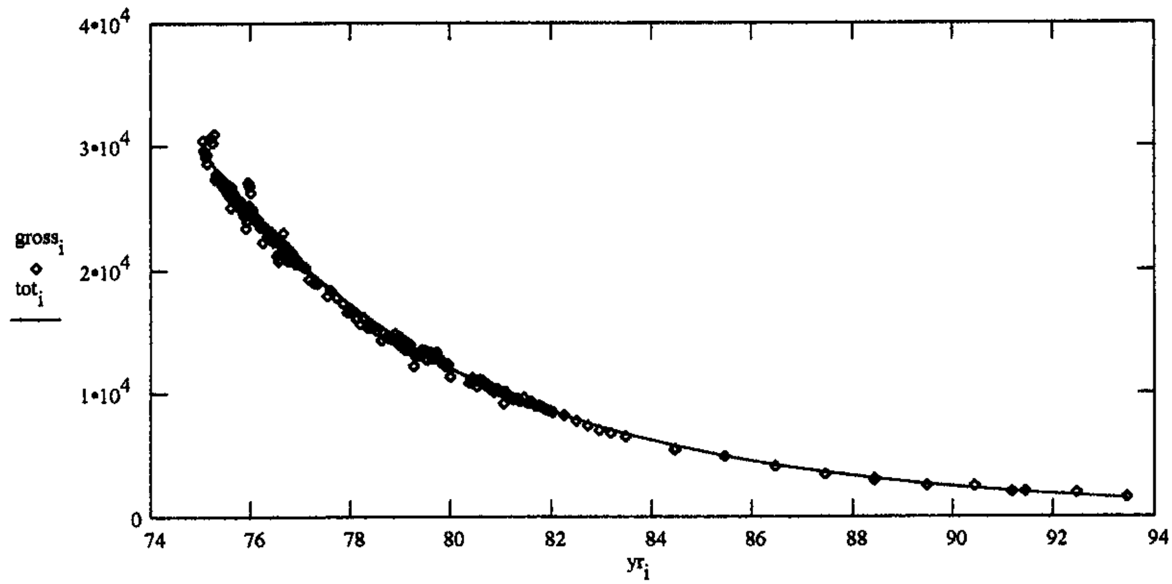
Eu variables are Ru-106 $\quad aeu := 14790$

$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \quad Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \quad Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}\cdot 1 \quad tot_i := Cs_i + Eu_i$

$gross_i := net_i$

Cs variables are Co-60

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}\right]\right]^2$$

Given

$ssq(acs, aeu) = 0 \quad 1 = 1$

$$\begin{bmatrix}\alpha cs \\ \alpha eu\end{bmatrix} := Minerr(acs, aeu)$$

$\alpha cs = 1.496 \cdot 10^4$ Co-60 $\quad \alpha eu = 1.47 \cdot 10^4$ Sb-125

$\frac{\alpha cs}{\alpha eu} = 1.018$

$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \quad Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \quad tot_i := Cs_i + Eu_i$

$out^{<0>} := yr \quad out^{<1>} := tot \quad$ WRITEPRN("twop40-80.txt") := out $\quad \frac{Eu_N}{Cs_N} = 0.11$

filein := "two128-140.txt" **Well 21-00-03**

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

N := last(yr) N = 199 i := 0..N k := 0..300 j := 0..299 $\tau eu := 2.77$

$\tau co := 5.27$ $\tau cs := 5.27$ aco := 0 acs := 400

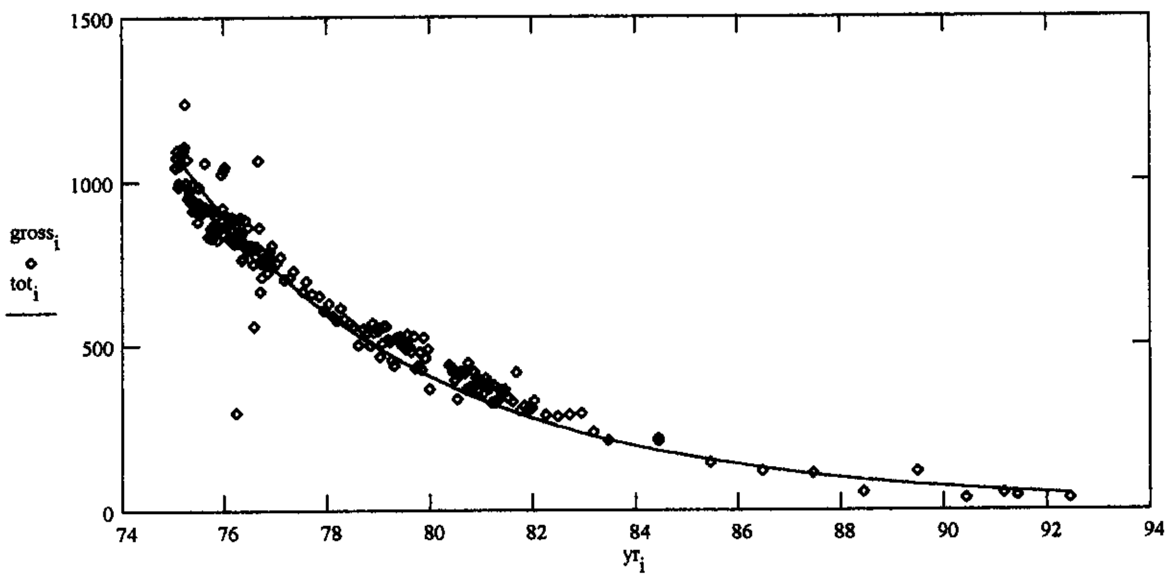
Eu variables are Sb-125 aeu := 700

$$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \quad Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \quad Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1 \quad tot_i := Cs_i + Eu_i$$

$gross_i := net_i$

Cs variables are Co-60

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[\frac{gross_i}{(yr_i - 74)^5} - \left[\frac{a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}}{(yr_i - 74)^5}\right]\right]^2$$

Given

ssq(acs, aeu) = 0 1 = 1

$$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := Minerr(acs, aeu)$$

$\alpha cs = 388.289$ Co-60 $\alpha eu = 688.076$ Sb-125

$$\frac{\alpha cs}{\alpha eu} = 0.564$$

$$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \quad Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \quad tot_i := Cs_i + Eu_i$$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop40-80.txt") := out

$$\frac{Eu_N}{Cs_N} = 0.223$$

Dry Well Survey Analysis - Notes

BY

Borehole 22-00-04 Total # Surveys 212 Probe Type 04

\# neutron surveys 2 # GR Surveys 210

Log Date: 1-16-75 1st 6-17-93 Last Presentation Plot Dates ______

(If different from 1st & Last)

Contamination Zone Depth(s): ______

Isotope from Spectral Survey: Cs & Co [illegible] Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			all peak @ 80' & 0-10
			with build up from 60-75

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

0-10 48-70 70-85

Analyst Name [signature] S/W ver TFGROSS 2.2

filein := "two48-70.txt" **Well 21-00-04**

A := READPRN(filein) $yr := A^{\langle 1 \rangle}$ $net := A^{\langle 7 \rangle}$ $bkg := A^{\langle 6 \rangle}$ $max := A^{\langle 4 \rangle}$

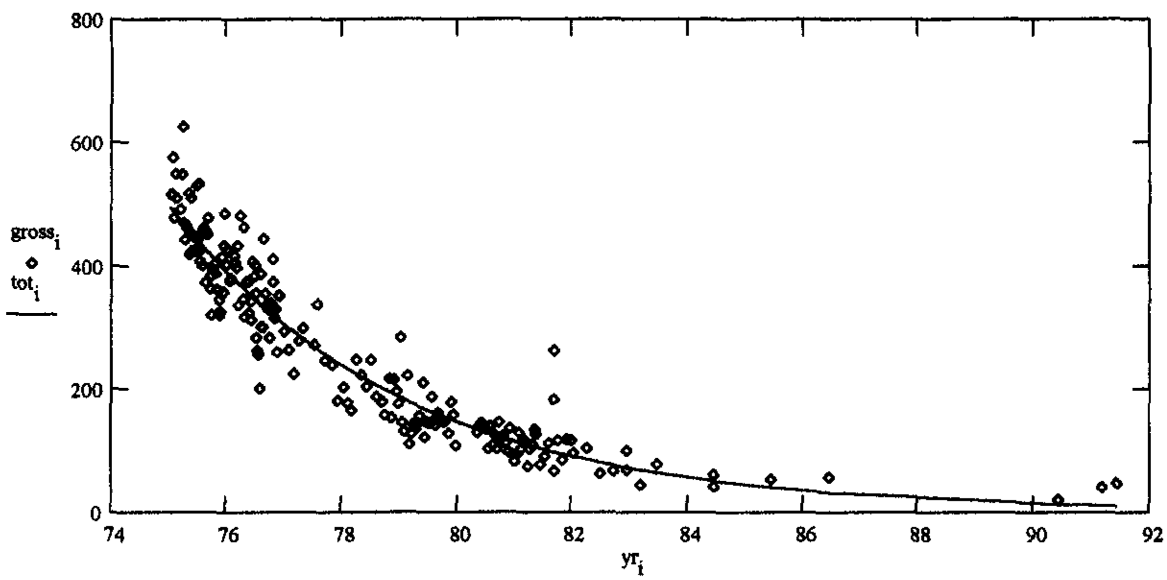
N := last(yr) N = 193 i := 0 .. N k := 0 .. 300 j := 0 .. 299 $\tau eu := 2.77$

$\tau co := 5.27$ $\tau cs := 5.27$ aco := 00 acs := 20 <u>Eu variables are Sb-125</u> aeu := 480

$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1$ $tot_i := Cs_i + Eu_i$

$gross_i := net_i$ *Cs variables are Co-60*

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

ssq(acs, aeu) = 0 1 = 1

$$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := \text{Minerr}(acs, aeu)$$

$\alpha cs = 19.557$ $\alpha eu = 485.548$

Co-60 Sb-125

$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $tot_i := Cs_i + Eu_i$ $\frac{\alpha cs}{\alpha eu} = 0.04$

$out^{\langle 0 \rangle} := yr$ $out^{\langle 1 \rangle} := tot$ WRITEPRN("twop48-70.txt") := out $\frac{Eu_N}{Cs_N} = 3.525$

filein := "two70-85.txt" **Well 21-00-04**

$A := READPRN(filein)$ $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

$N := last(yr)$ $N = 199$ $i := 0..N$ $k := 0..300$ $j := 0..299$ $\tau eu := 1$

$\tau co := 5.27$ $\tau cs := 5.27$ $aco := 00$ $acs := 270$

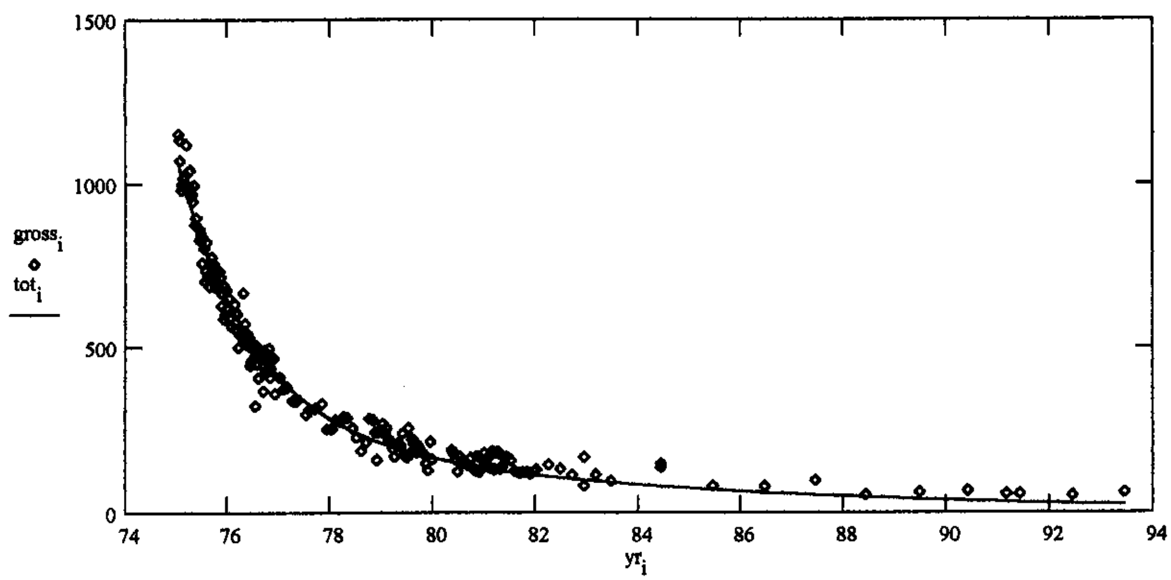
Eu variables are Ru-106 $aeu := 820$

$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}\cdot 1}$ $tot_i := Cs_i + Eu_i$

$gross_i := net_i$

Cs variables are Co-60

This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

$ssq(acs, aeu) = 0$ $1 = 1$

$$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := Minerr(acs, aeu)$$

$\alpha cs = 272.956$ Co-60 $\alpha eu = 818.978$ Ru-106

$\frac{\alpha cs}{\alpha eu} = 0.333$

$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $tot_i := Cs_i + Eu_i$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop70-85.txt") := out $\frac{Eu_N}{Cs_N} = 9.422\cdot 10^{-5}$

Dry Well Survey Analysis - Notes

BY

Borehole 22-00-10 Total # Surveys 389 Probe Type 04

\# neutron surveys 4 # GR Surveys 385

Log Date: 1-9-75 1st 10-4-93 Last Presentation Plot Dates

(If different from 1st & Last)

Contamination Zone Depth(s):

Isotope from Spectral Survey: Cs surf to 45' Max Survey Depth 120

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			no show of Cs at 50'
			stack looks clean also

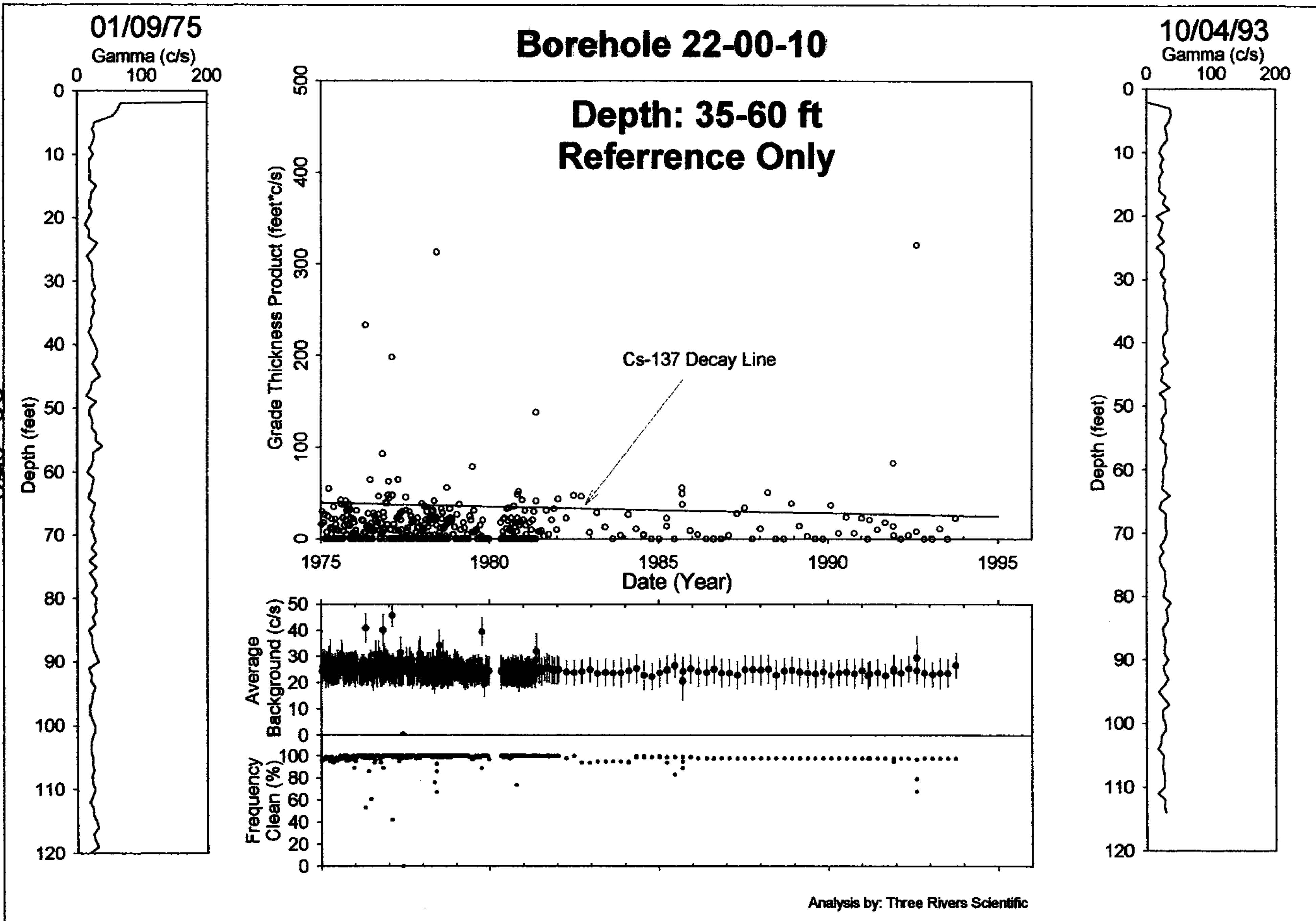
BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

higher than normal Cs for no show in TF GR

Analyst Name Russ Randall S/W ver TFGROSS2.2



HNF-3532 -REV0

920 00

Borehole 22-01-01

Contamination (Cs-137) from 0-6 feet is Tank Farm Activity
Contamination (Cs-137) from 6-15 feet appears Stable

Grade thickness product from 0 to 6 feet is intermittently changing from 1975 to 1987 which is indicative of tank farm activities such as a transfer line activity. The grade thickness product for this interval is decreasing consistent with Cs-137 (HPGe identified) from 1987 to 1993.

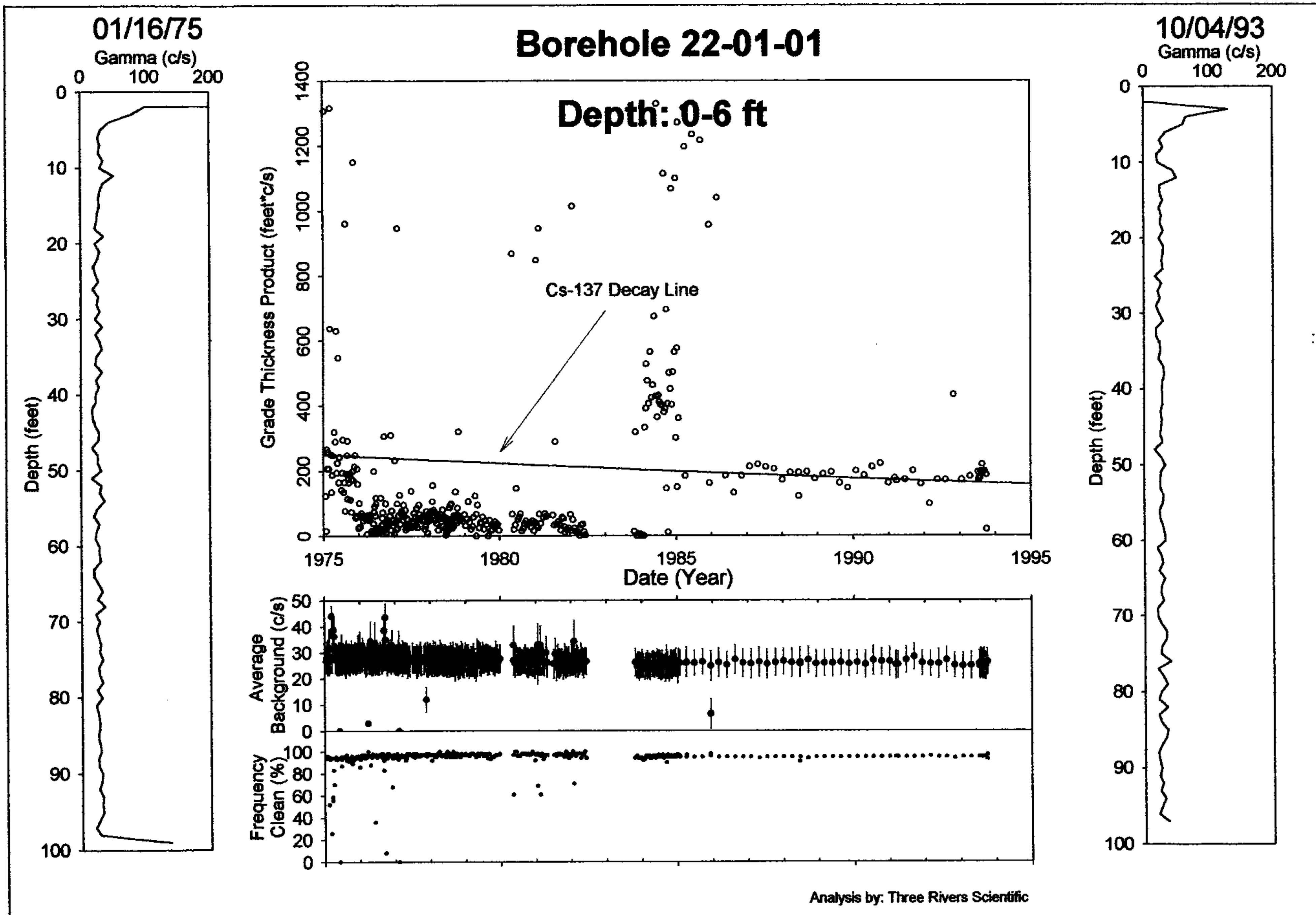
Grade thickness product from 6 to 15 feet is decreasing consistent with Cs-137 (HPGe identified) from 1975 to 1993. The levels are near threshold.

Gross Gamma Survey Information

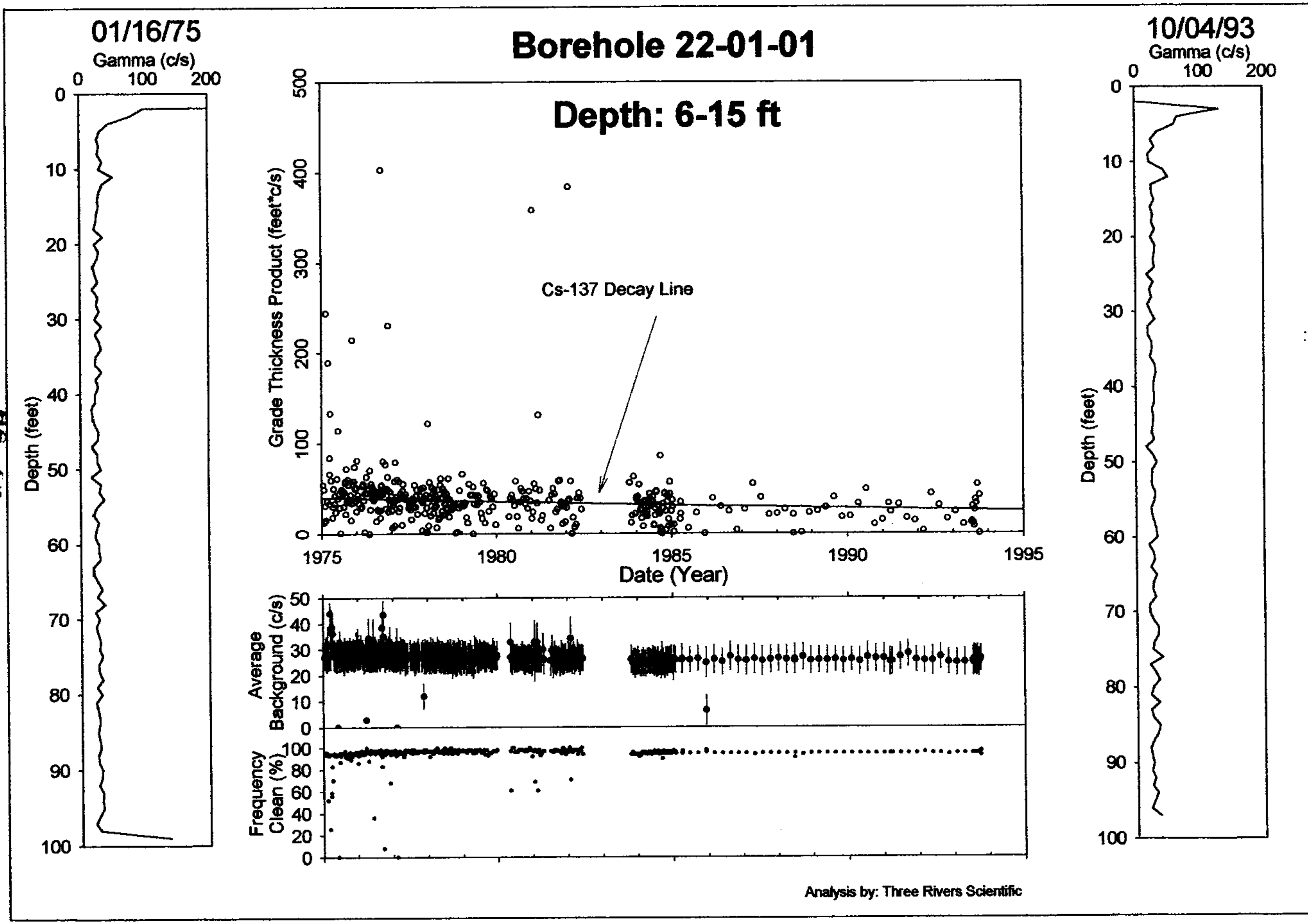
Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/16/1975
Last Survey Date :	10/4/1993
Number Surveys :	406

Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-6 Tank farm activity, 6-15 Stable	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	



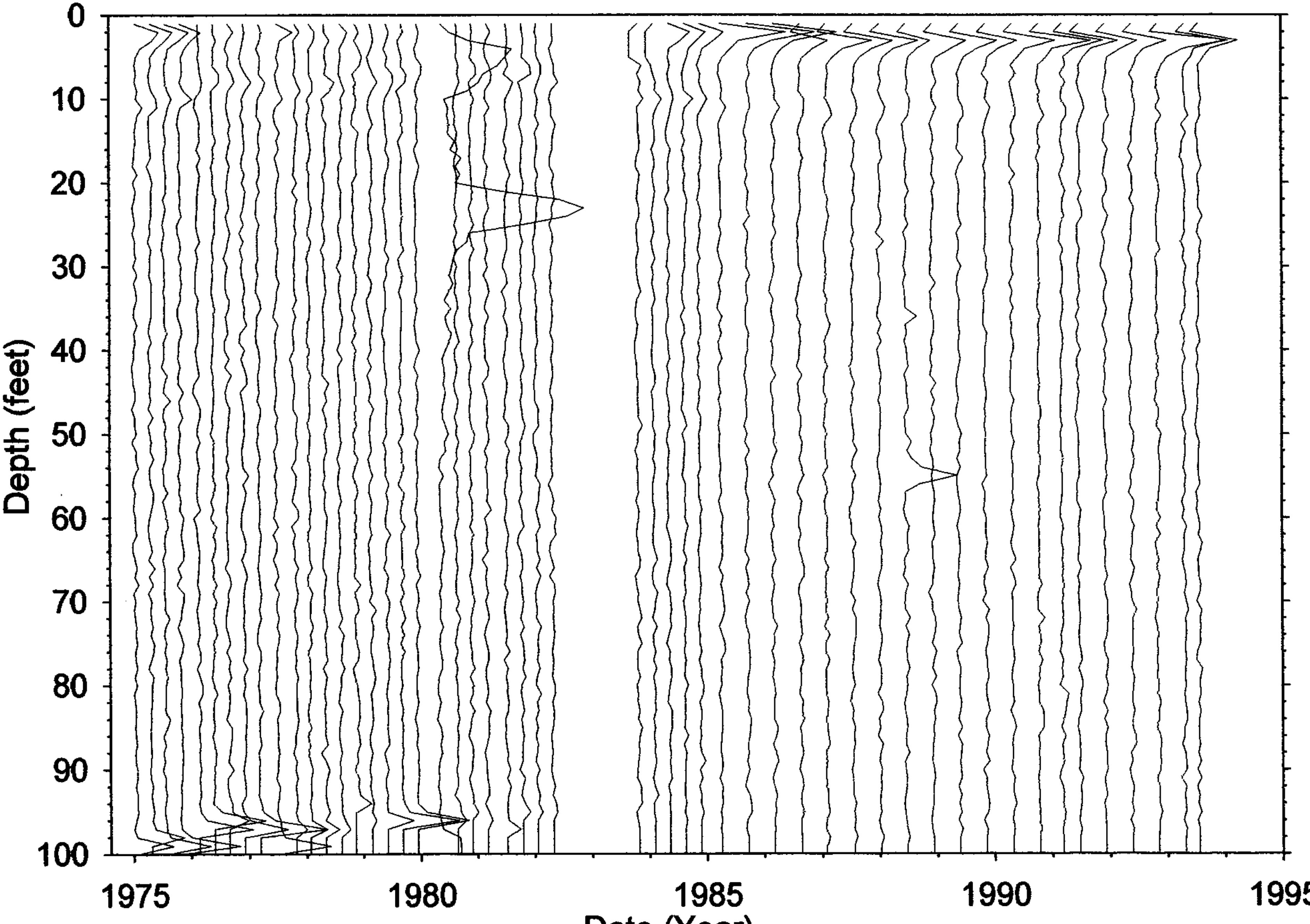
Borehole 22-01-01
01/16/75
Gamma (c/s)
Depth (feet)
Depth: 0-6 ft
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
10/04/93
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific



HNF-3532 -REV0

00 079

Borehole 22-01-01



HNF-3532 -REV0

080 00

Borehole 22-01-03

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity

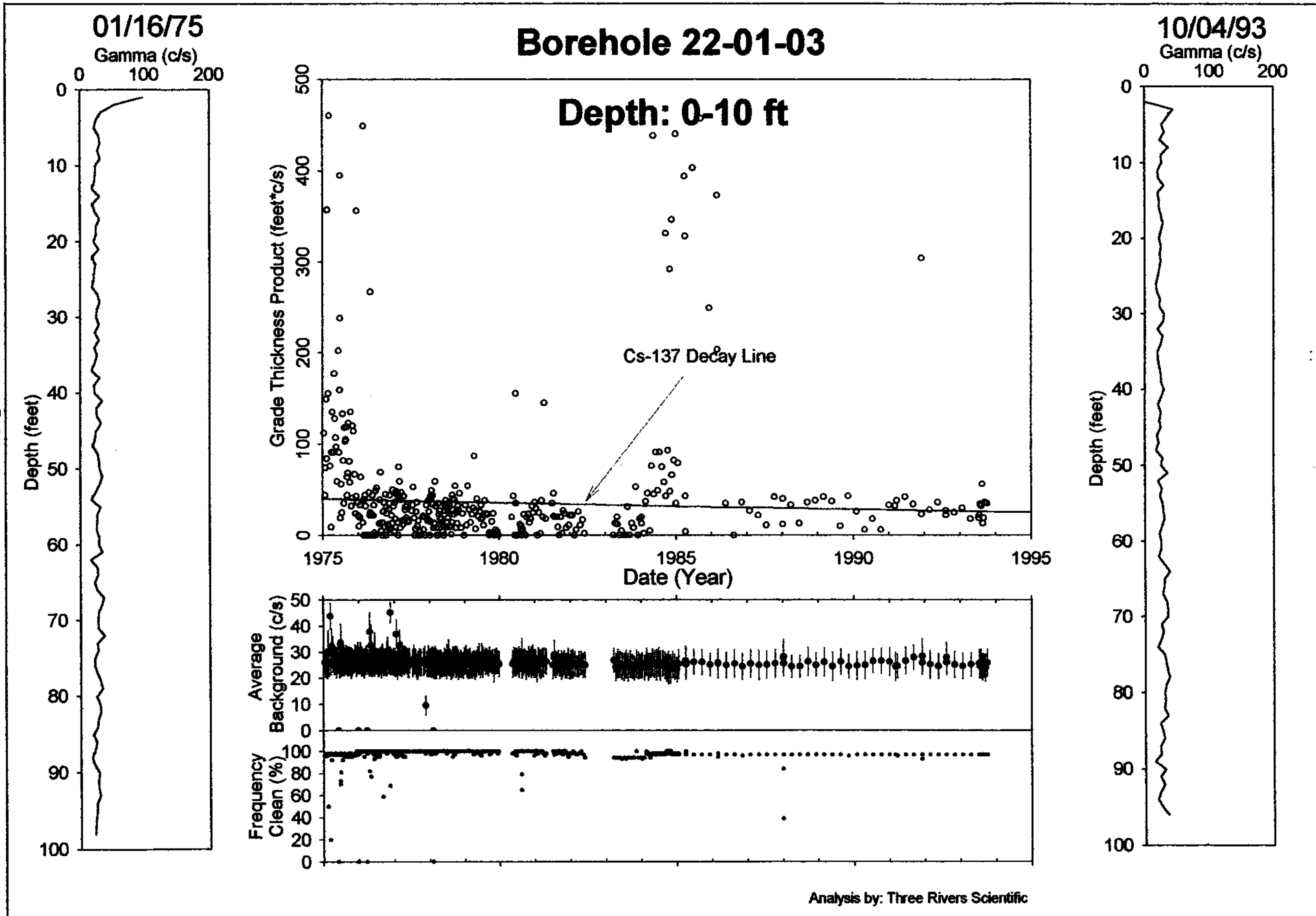
Grade thickness product from 0 to 10 feet is intermittently changing from 1975 to 1986 which is indicative of tank farm activities such as a transfer line activity. The grade thickness product for this interval is decreasing consistent with Cs-137 (HPGe identified) from 1986 to 1993.

Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/16/1975
Last Survey Date :	10/4/1993
Number Surveys :	395

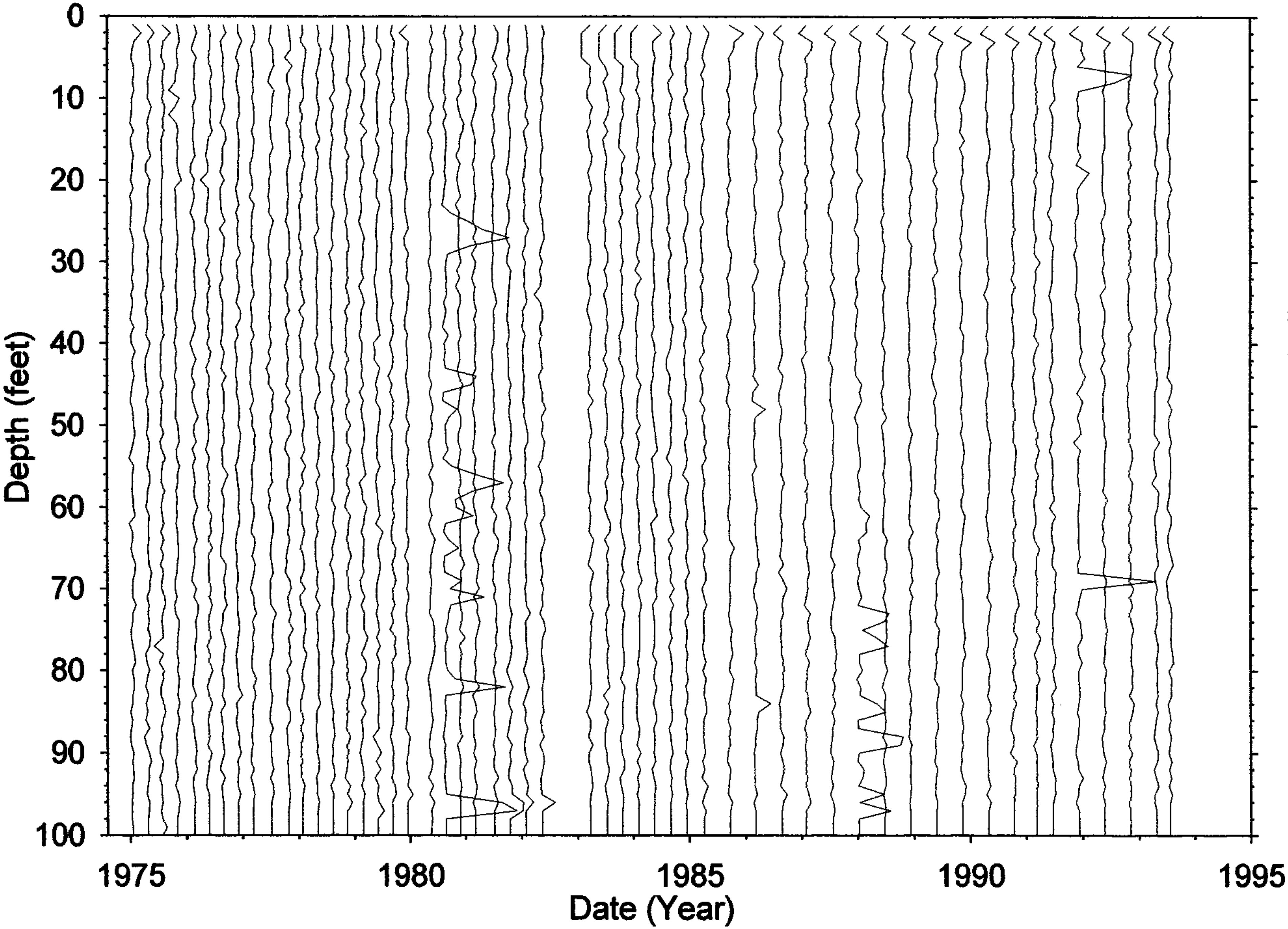
Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 Tank farm activity	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	



Borehole 22-01-03
Depth: 0-10 ft
01/16/75
Gamma (c/s)
Depth (feet)
10/04/93
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

Borehole 22-01-03



Borehole 22-01-04

Contamination (Cs-137) from 0-15 feet is Tank Farm Activities
Contamination (Cs-137) from 15-30 feet is Stable
Contamination (Co-60 & Sb-125) from 30-60 feet is Stable

Grade thickness product from 0 to 15 feet is changing erratically indicative of tank farm activities such as changes in transfer lines.

Grade thickness product from 15 to 30 feet is decreasing consistent with Cs-137 (HPGe identified) 1975 to 1993, within systematic limitations.

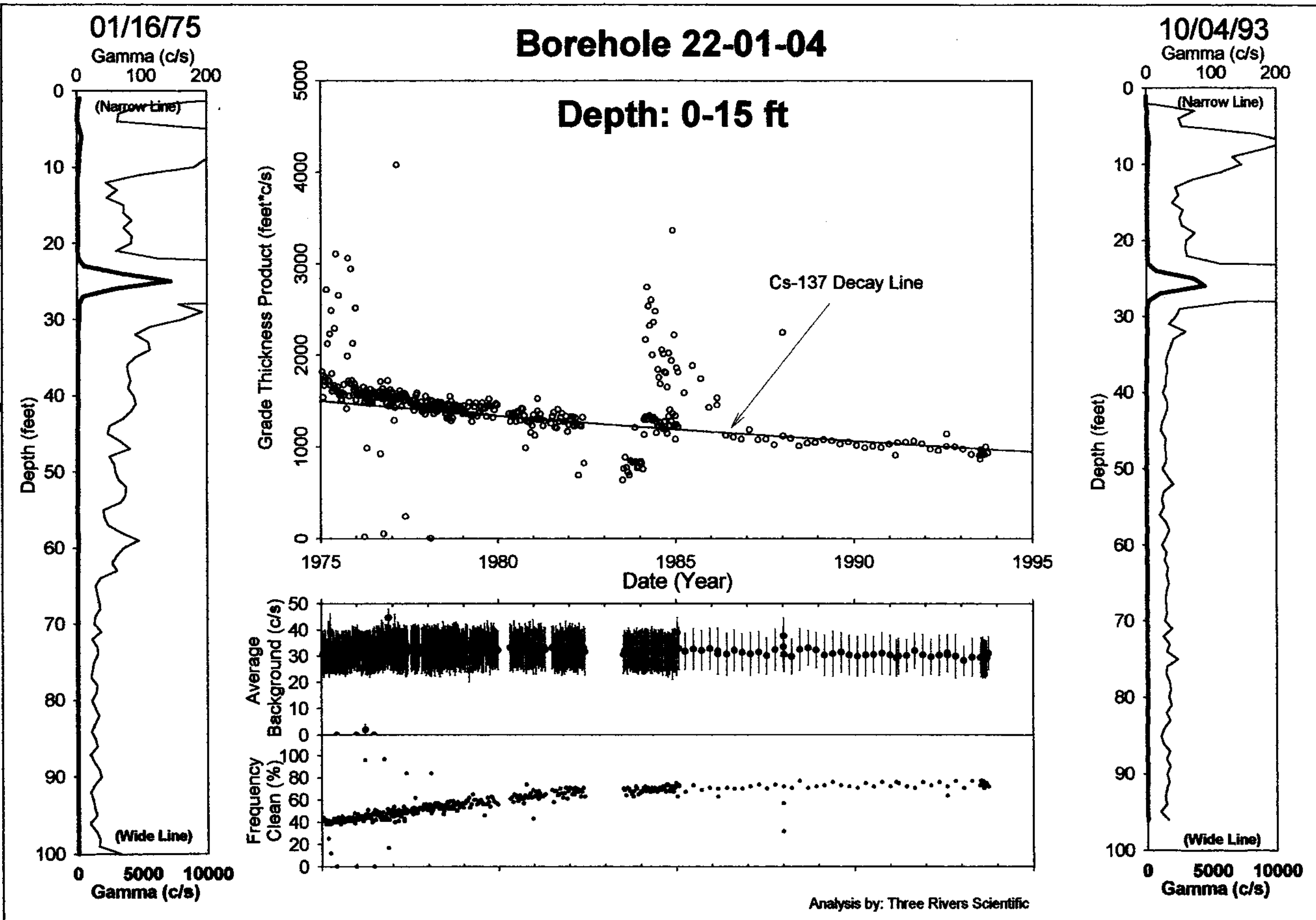
Grade thickness product from 30 to 60 feet is decreasing consistent with Co-60 (HPGe identified) & Sb-125 (hypothesis) from 1975 to 1993, within systematic limitations. The least squares fit results in gross gamma contribution ratio of Sb-125 to Co-60 of 6.38 as of Oct 1993.

Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/16/1975
Last Survey Date :	10/4/1993
Number Surveys :	408

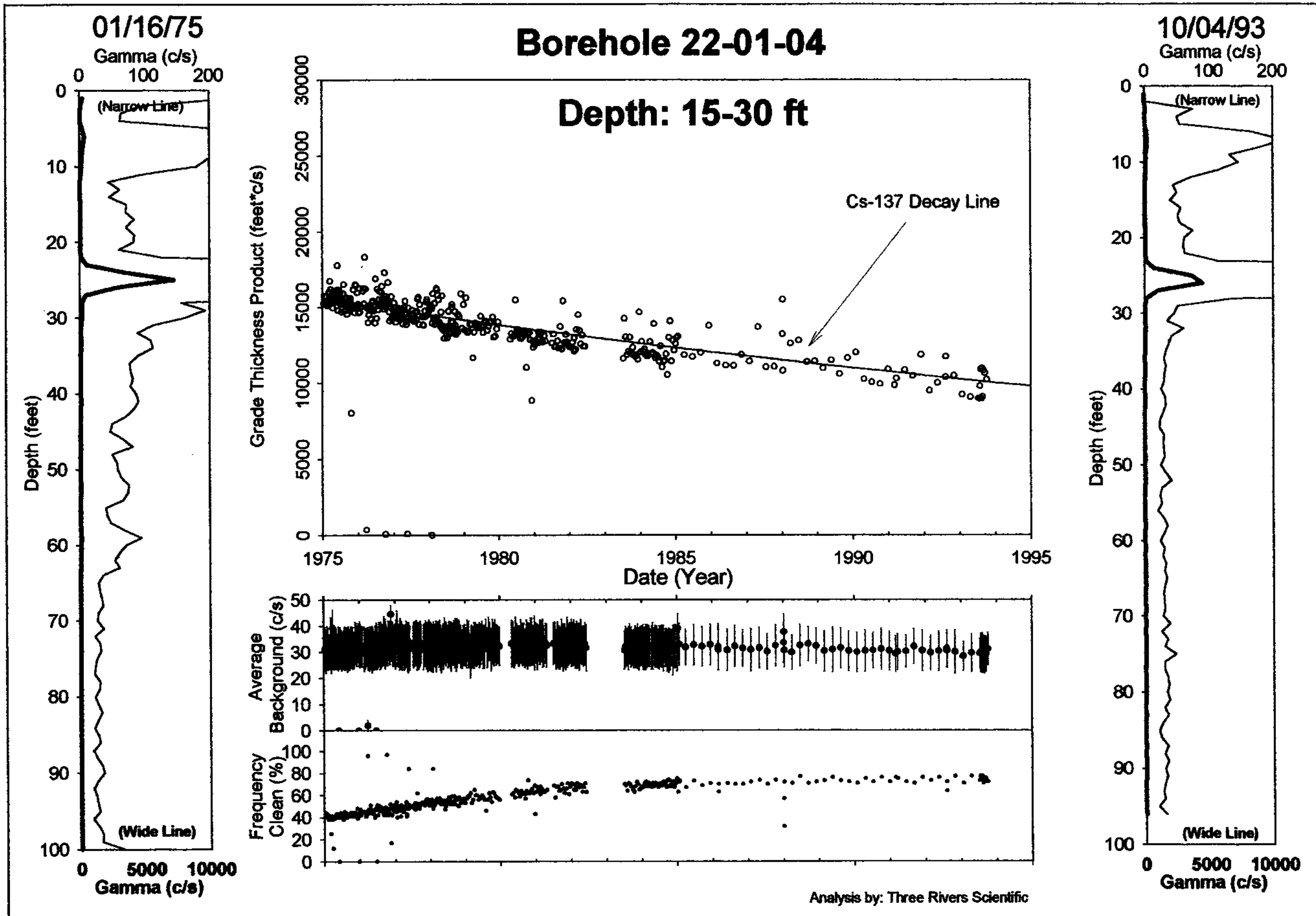
Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-15 Tank Farm Activity, 15-30 & 30-60 Stable	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	

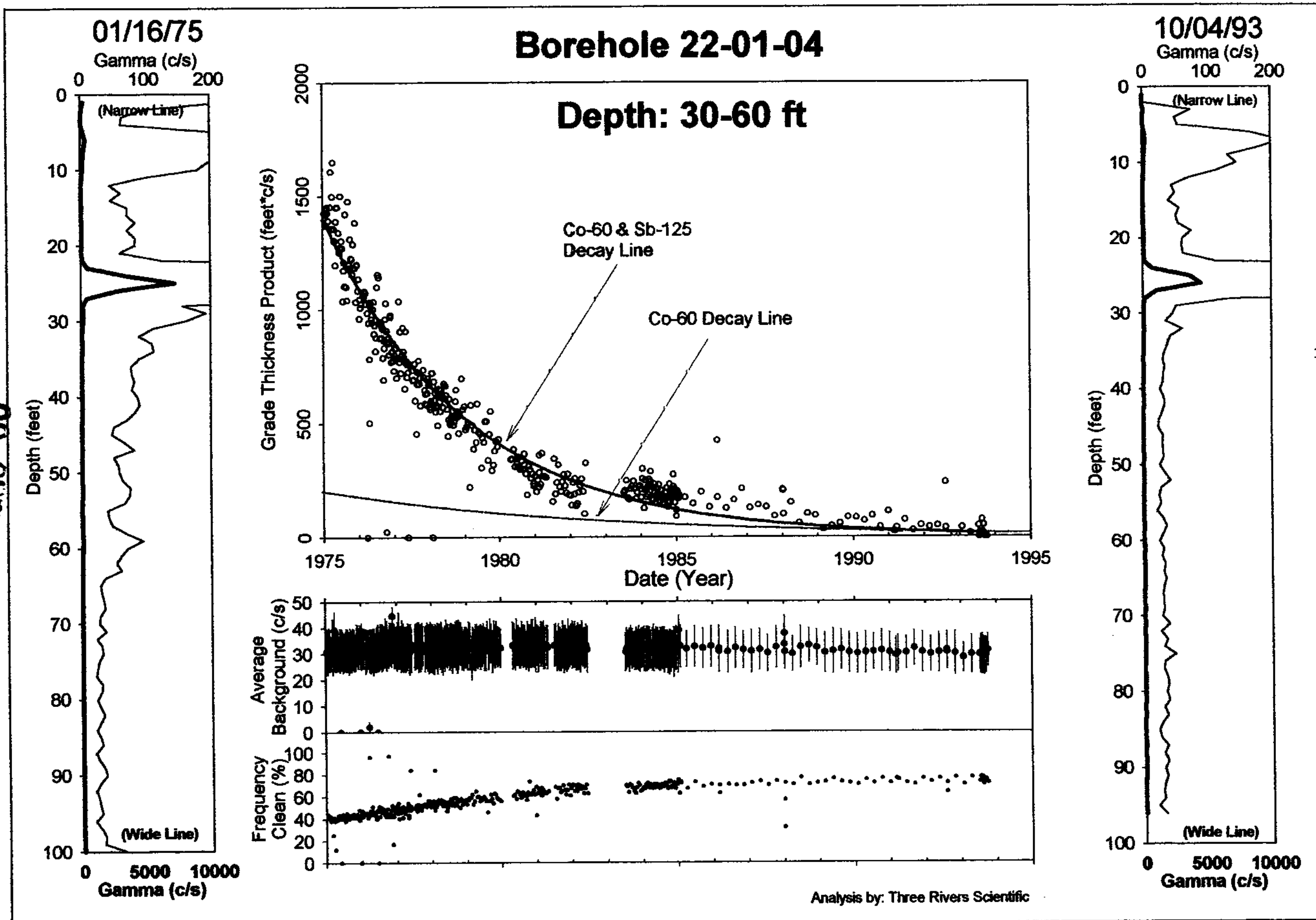


Borehole 22-01-04
Depth: 0-15 ft
01/16/75
10/04/93
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

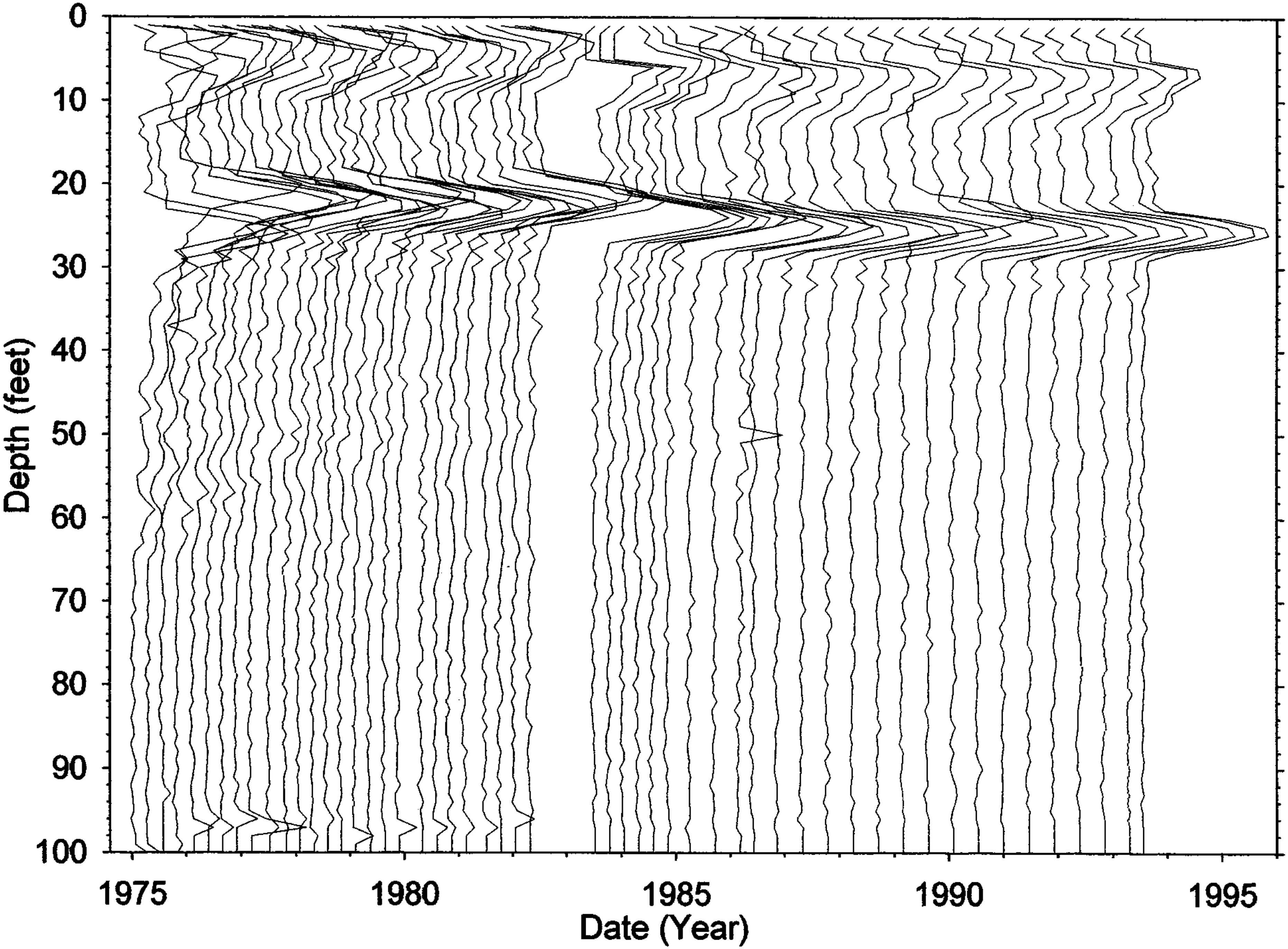
00 085



Borehole 22-01-04
Depth: 15-30 ft
01/16/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
10/04/93
Analysis by: Three Rivers Scientific


Borehole 22-01-04
Depth: 30-60 ft
01/16/75
Gamma (c/s)
0
100
200
(Narrow Line)
(Wide Line)
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
0
5000
10000
Gamma (c/s)
Grade Thickness Product (feet*c/s)
0
500
1000
1500
2000
Co-60 & Sb-125
Decay Line
Co-60 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average
Background (c/s)
0
10
20
30
40
50
Frequency
Clean (%)
0
20
40
60
80
100
Analysis by: Three Rivers Scientific
10/04/93
Gamma (c/s)
0
100
200
(Narrow Line)
(Wide Line)
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
0
5000
10000
Gamma (c/s)

Borehole 22-01-04



HNF-3532 -REV0

Borehole 22-01-07

Contamination (Cs-137) from 0-6 feet is Tank Farm Activity
Contamination (Cs-137) from 6-15 feet is Stable
Contamination (Co-60) from 40-55 feet is Stable

Grade thickness product from 0 to 6 feet is intermittently changing from 1975 to 1987 which is indicative of tank farm activities such as a transfer line activity. The grade thickness product for this interval is decreasing consistent with Cs-137 (HPGe identified) from 1987 to 1993.

Grade thickness product from 6 to 15 feet is decreasing consistent with Cs-137 (HPGe identified) from 1975 to 1993. The levels are near threshold.

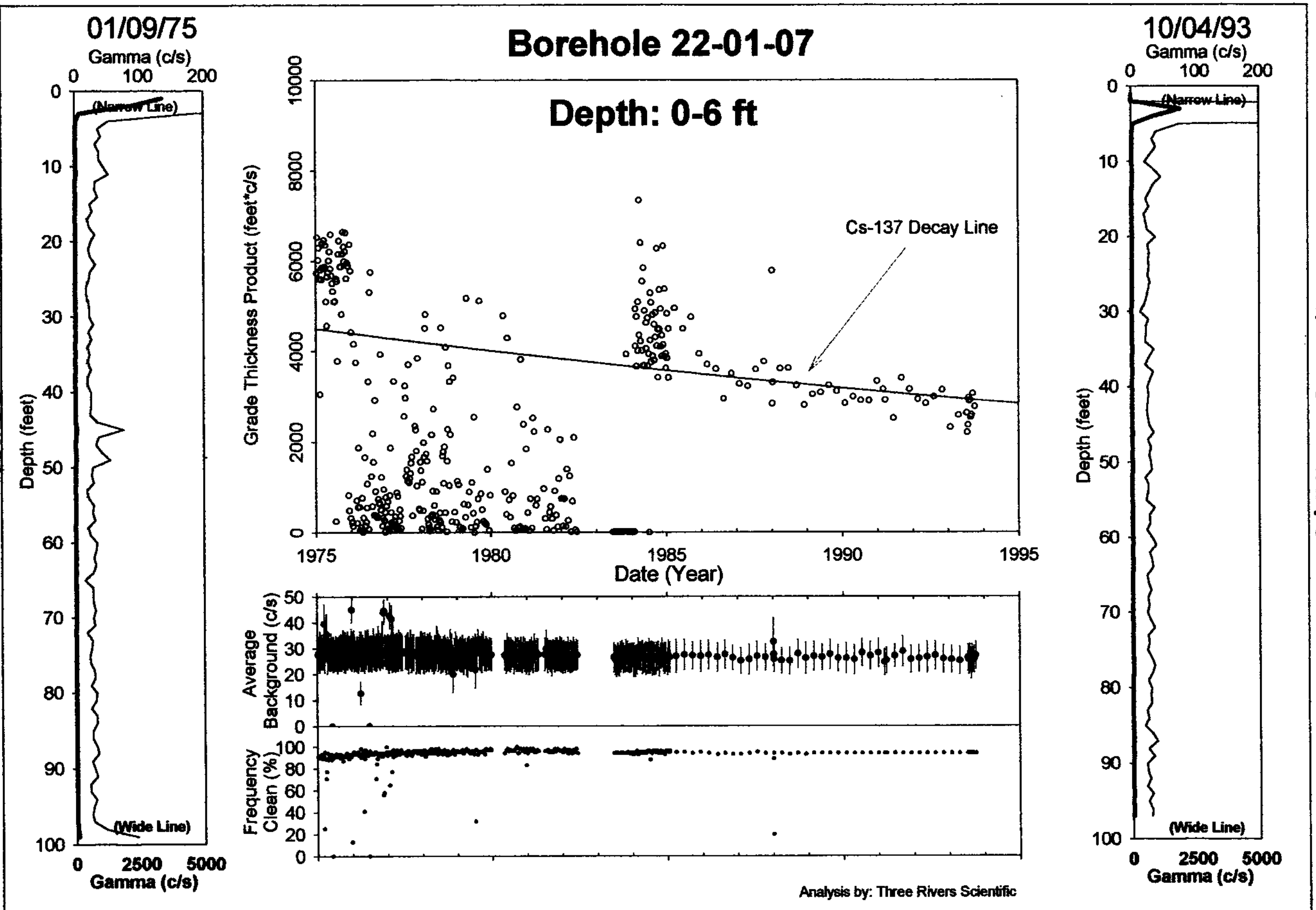
Grade thickness product from 40 to 55 feet is decreasing consistent with Co-60 (HPGe identified) from 1975 to 1985.

Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/9/1975
Last Survey Date :	10/4/1993
Number Surveys :	394

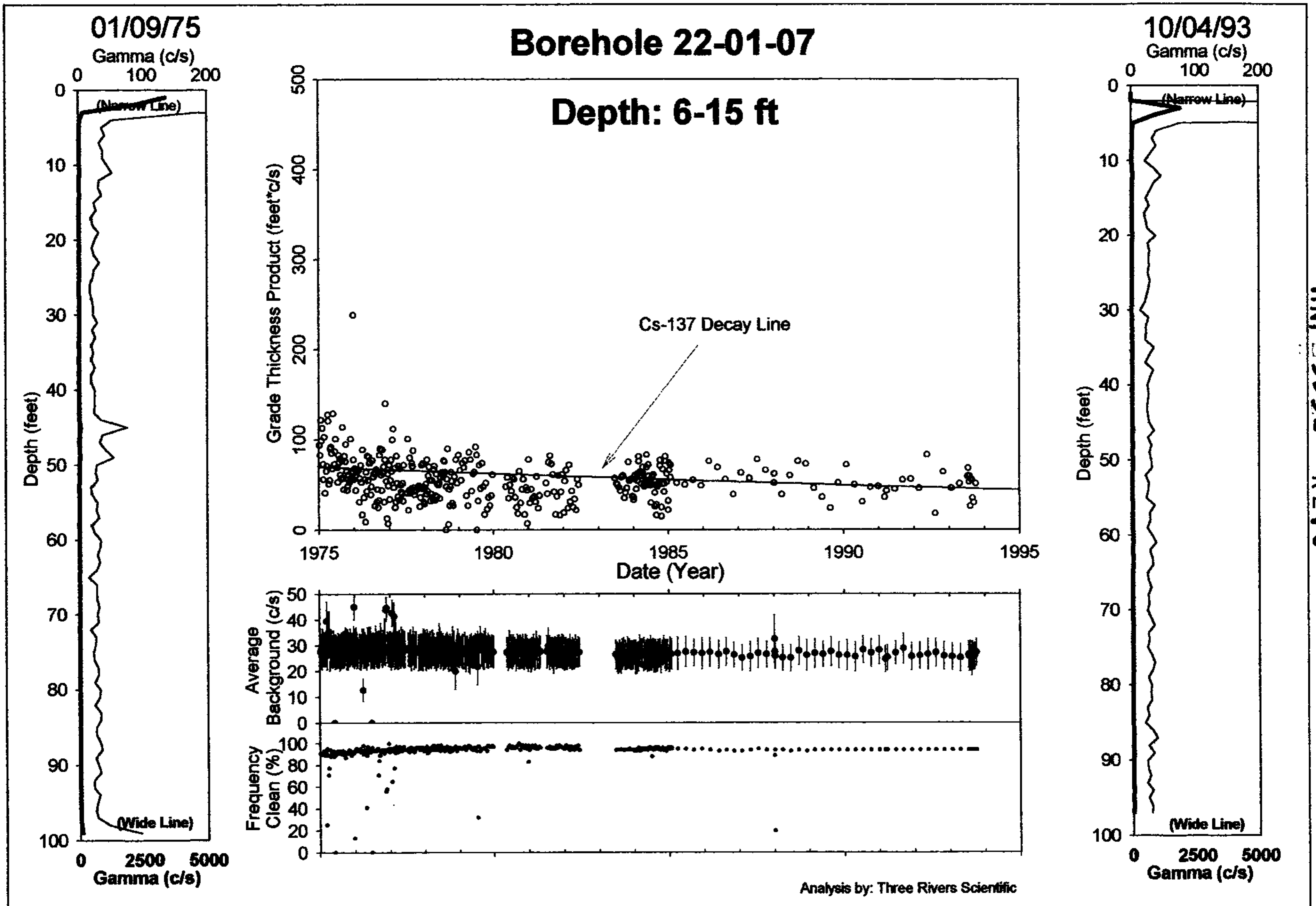
Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-6 Tank farm activity 6-15 & 40-55 Stable	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	

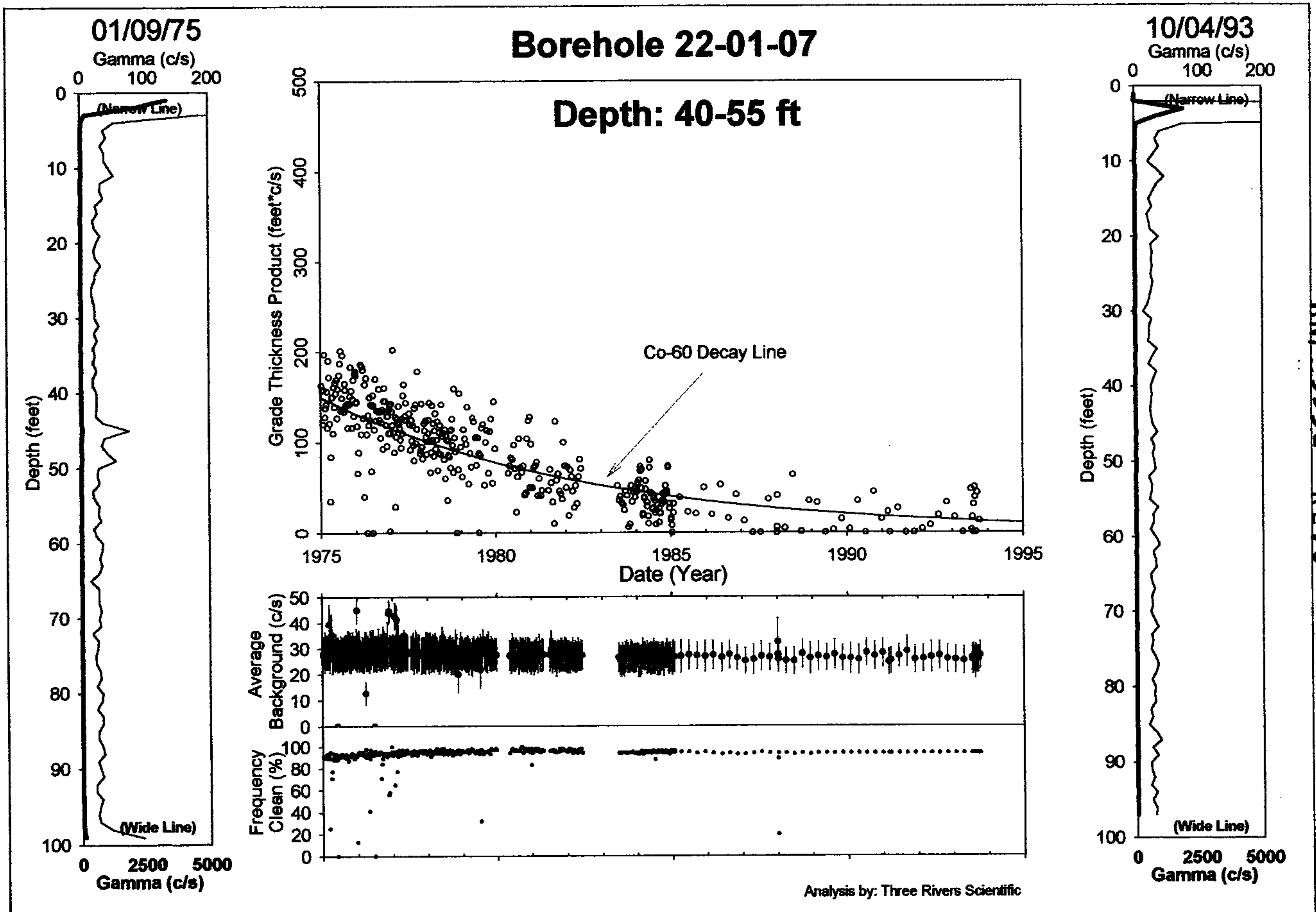


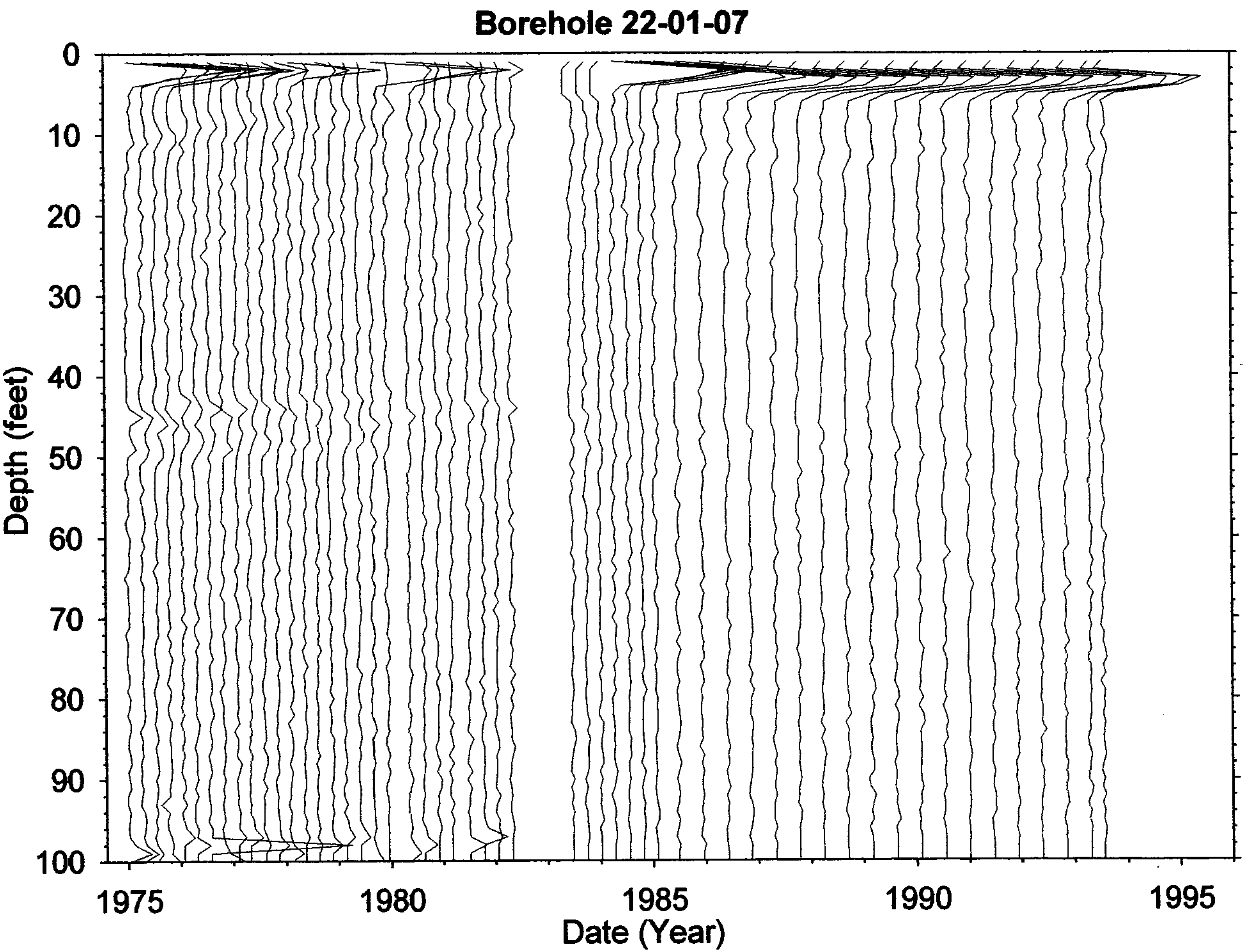
060 00

HNF-3532 -REV0



Borehole 22-01-07
Depth: 6-15 ft
01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
10/04/93
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Analysis by: Three Rivers Scientific


Borehole 22-01-07
Depth: 40-55 ft
01/09/75
10/04/93
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific



HNF-3532 -REV0

00 093

Borehole 22-01-10

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity
Contamination (Cs-137) from 15-25 feet is Stable
Contamination (Cs-137 & Co-60) from 25-44 feet is Stable

Grade thickness product from 0 to 10 feet is intermittently changing from 1975 to 1987 which is indicative of tank farm activities such as a transfer line activity. The grade thickness product for this interval is decreasing consistent with Cs-137 (HPGe identified) from 1987 to 1993.

Grade thickness product from 15 to 25 feet is decreasing consistent with Cs-137 (HPGe identified) from 1975 to 1993.

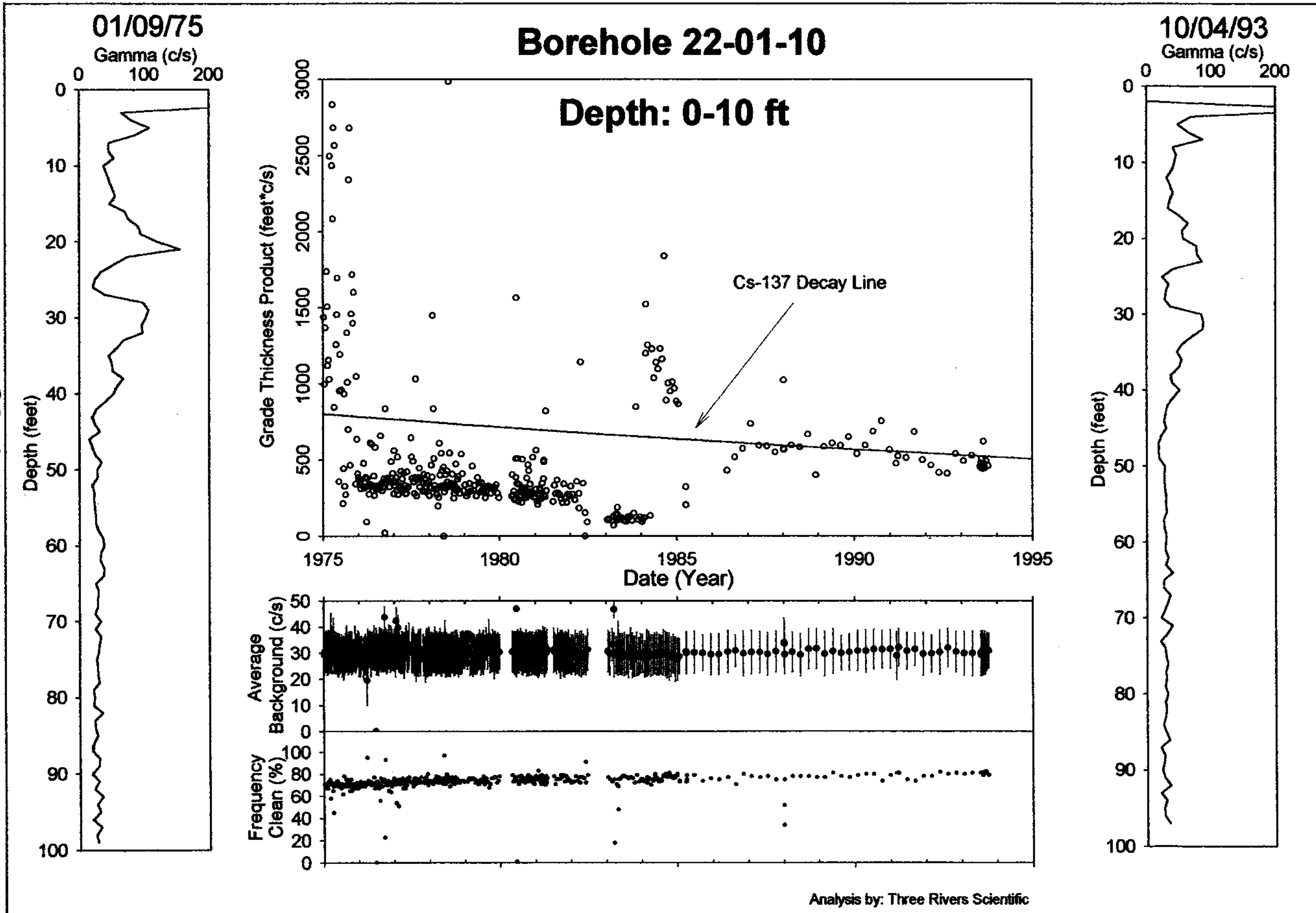
Grade thickness product from 25 to 44 feet is decreasing consistent with Cs-137 (HPGe identified) & Co-60 (hypothesis) from 1975 to 1993. The least squares fit results in gross gamma contribution ratio of Co-60 to Cs-137 of 0.03 as of Oct 1993. The very low level of Co-60 is only required to have the grade thickness product follow a consistent trend.

Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/9/1975
Last Survey Date :	10/4/1993
Number Surveys :	419

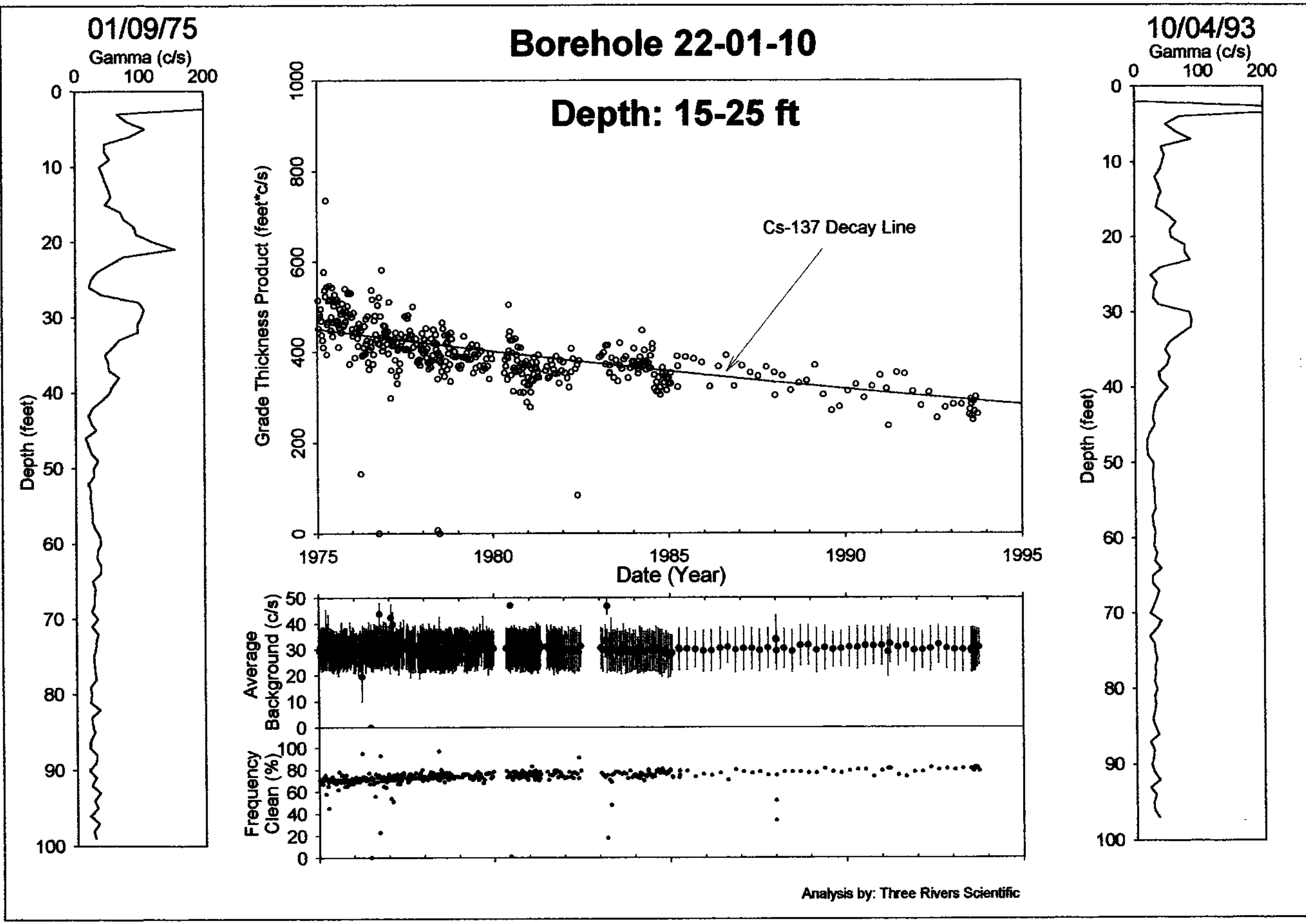
Analysis Notes

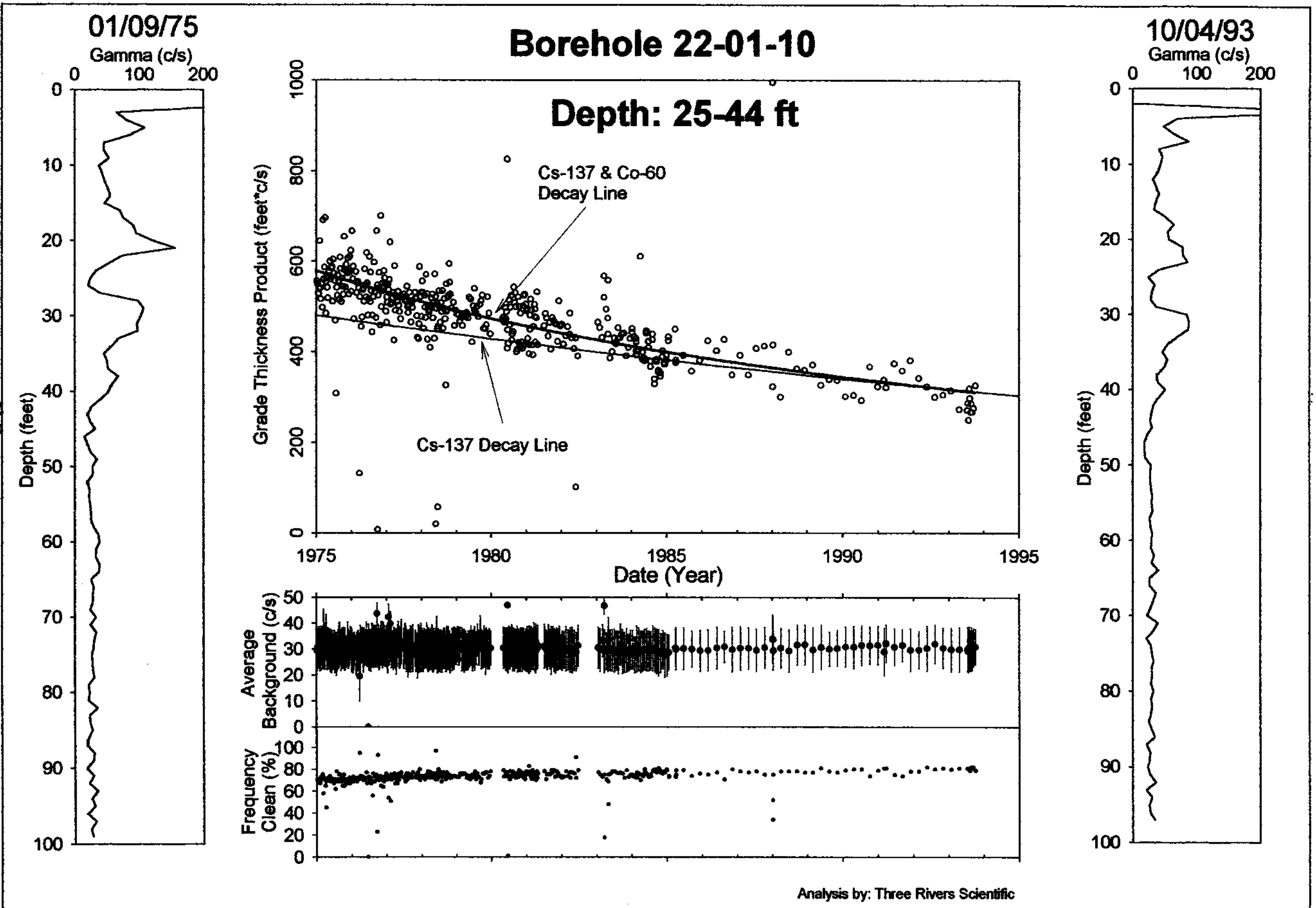
Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 Tank Farm Activity, 15-25 & 25-44 Stable,	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	



Borehole 22-01-10
Depth: 0-10 ft
01/09/75
Gamma (c/s)
Depth (feet)
10/04/93
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

00 095

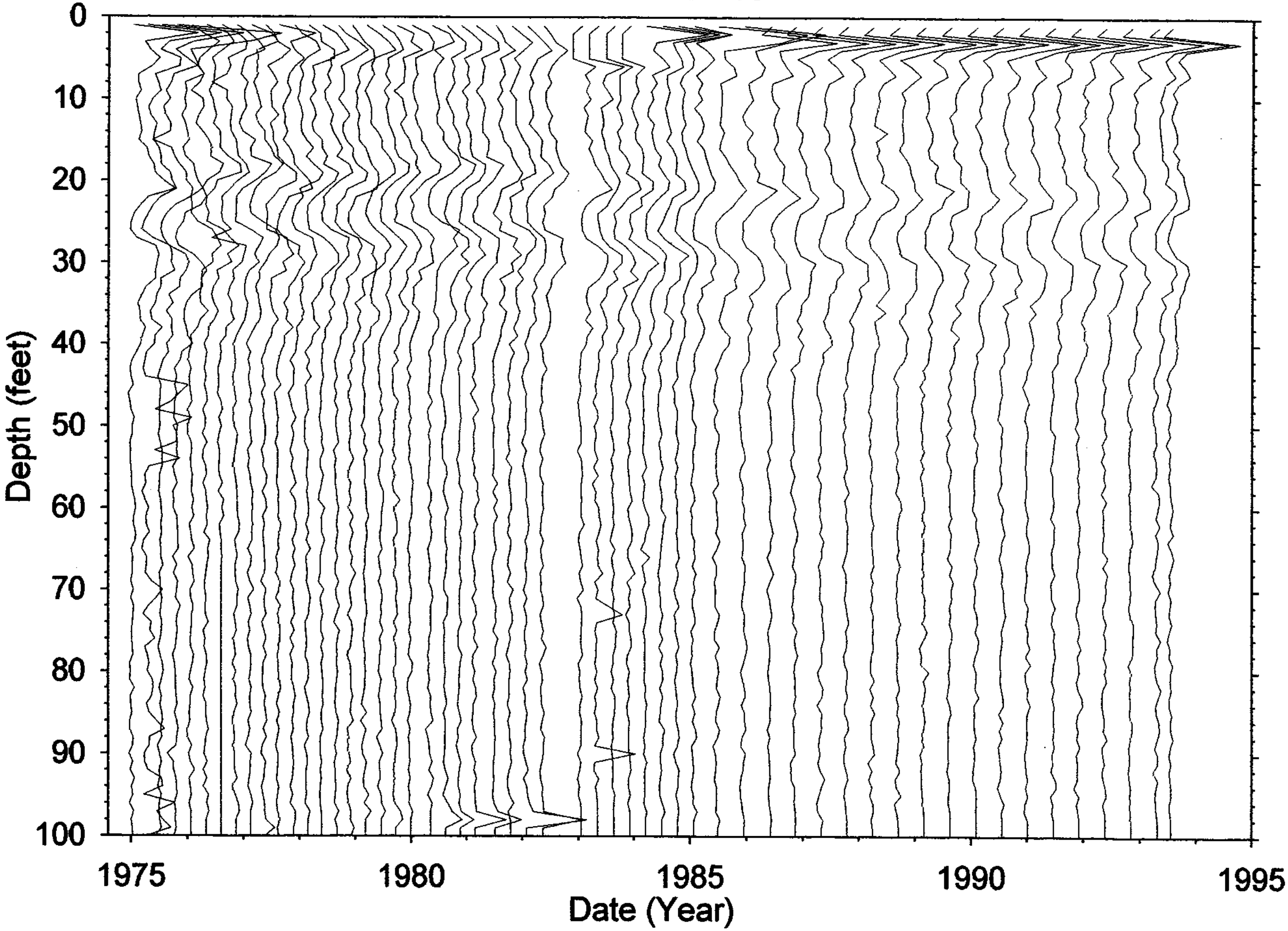

Borehole 22-01-10
Depth: 15-25 ft
01/09/75
Gamma (c/s)
Depth (feet)
10/04/93
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific



Borehole 22-01-10
Depth: 25-44 ft
01/09/75
Gamma (c/s)
Depth (feet)
10/04/93
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 & Co-60 Decay Line
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

00 097

Borehole 22-01-10



Dry Well Survey Analysis - Notes

Borehole BY 22-01-01 Total # Surveys 408 Probe Type 04

\# neutron surveys 2 # GR Surveys 406

Log Date: 1-16-75 1st 10-4-93 Last Presentation Plot Dates ______

(If different from 1st & Last)

Contamination Zone Depth(s): ______

Isotope from Spectral Survey: Cs low levels 10t @ surface Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			0-10 has shown
			after stack 0-6 & 6-15

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Analyst Name [signature] S/W ver TFGROSS 2.2

Dry Well Survey Analysis - Notes

Borehole 22-01-03 Total # Surveys 397 Probe Type 04
neutron surveys 2 # GR Surveys 395
Log Date: 1-11-75 1st 10-4-93 Last Presentation Plot Dates ______
(If different from 1st & Last)

Contamination Zone Depth(s): 0-10
Isotope from Spectral Survey: Cs Yes except @ surface Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			Near surface only intermittent
			and trace

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

0-10 feet intermittent

Analyst Name Rene Randall S/W ver TFGR0SS2.2

Dry Well Survey Analysis - Notes

BY

Borehole 22-01-04 Total # Surveys 410 Probe Type 04

neutron surveys 2 # GR Surveys 408

Log Date: 1-16-75 1st 10-4-93 Last Presentation Plot Dates ______
(If different from 1st & Last)

Contamination Zone Depth(s): ______

Isotope from Spectral Survey: Cs + Co Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			2-15 Cs Peak 22 Cs
			30-60 Co from Hi Zones

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

0-15 15-30 30-60

Analyst Name [signature] S/W ver TFGROSS 2.2

filein := "two30-60.txt" **Well 21-01-04**

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

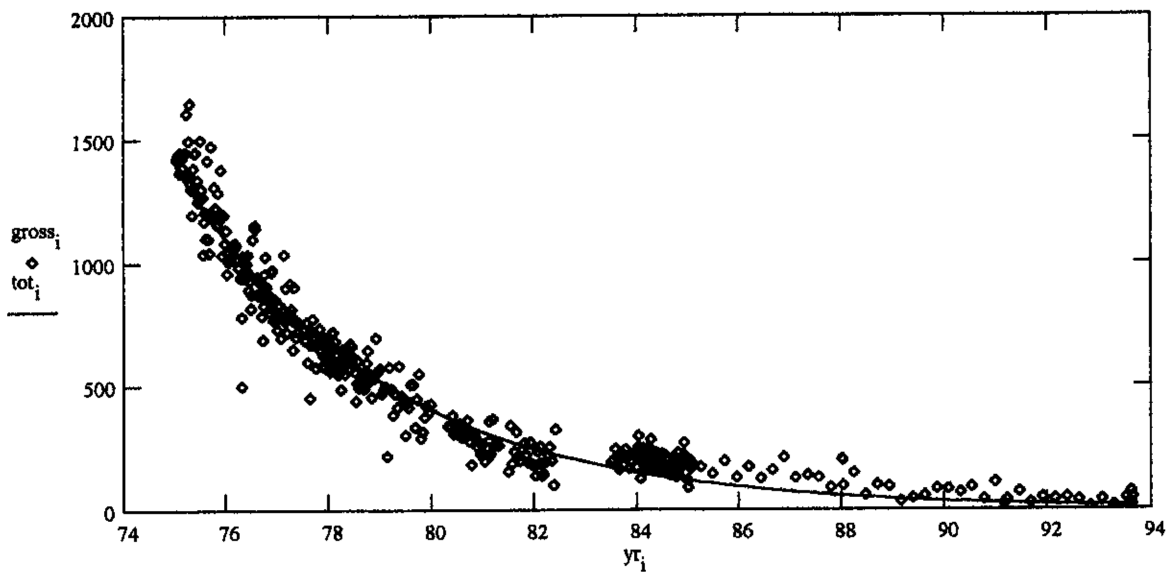
$N := last(yr)$ $N = 391$ $i := 0..N$ $k := 0..300$ $j := 0..299$ $\tau eu := 2.77$

$\tau co := 5.27$ $\tau cs := 5.27$ $aco := 00$ $acs := 24$ Eu variables are Sb-125 $aeu := 1384$

$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1$ $tot_i := Cs_i + Eu_i$

$gross_i := net_i$ Cs variables are Co-60

This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

$ssq(acs, aeu) = 0$ $1 = 1$

$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := Minerr(acs, aeu)$

$\alpha cs = 24$ Co-60 $\alpha eu = 1.384 \cdot 10^3$ Sb-125

$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $tot_i := Cs_i + Eu_i$ $\frac{\alpha cs}{\alpha eu} = 0.017$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop.txt") := out $\frac{Eu_N}{Cs_N} = 6.287$

Dry Well Survey Analysis - Notes

Borehole 22-01-07 Total # Surveys 396 Probe Type 04

\# neutron surveys 2 # GR Surveys 394

Log Date: 1-9-75 1st 10-4-93 Last Presentation Plot Dates ______

(If different from 1st & Last)

Contamination Zone Depth(s): ______

Isotope from Spectral Survey: Cs low but @ surf Co very low 45-50 Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

40-60 on guess
from stack 0-6 6-15 40-50
looked at 40-50 & 40-60 both have linear drop?

Analyst Name [signature]

S/W ver TFGROSS 2.2

BY

Dry Well Survey Analysis - Notes

Borehole 22-01-~~0~~10 Total # Surveys 421 Probe Type 04

\# neutron surveys 2 # GR Surveys 419

Log Date: 1-9-75 1st 10-4-93 Last Presentation Plot Dates ______ (If different from 1st & Last)

Contamination Zone Depth(s): ______

Isotope from Spectral Survey: Cs Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			looks like no depth shift required

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

0-10 15-25 25-44

→ changes based on depth? or real?

Analyst Name Russ Randall S/W ver TFGROSS 2.2

filein := "two.txt"

Well 21-01-10

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

N := last(yr)   N = 407   i := 0 .. N   k := 0 .. 300   j := 0 .. 299 $\tau eu := 5.27$

$\tau co := 5.27$ $\tau cs := 30.17$ aco := 00   acs := 463

Eu variables are Co-60

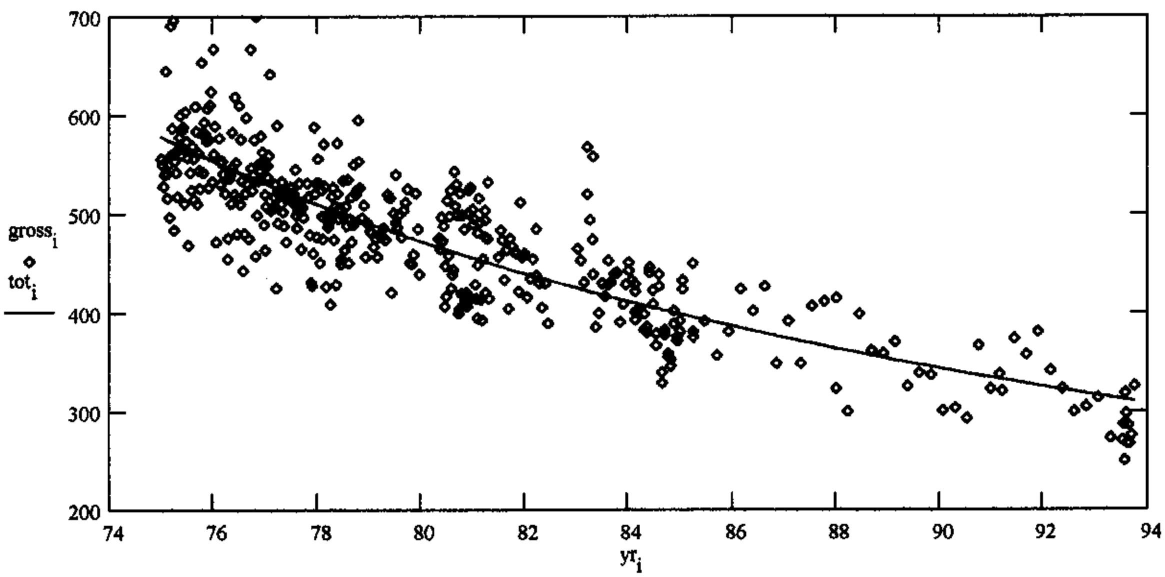
aeu := 116

$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1$ $tot_i := Cs_i + Eu_i$

$gross_i := net_i$

Cs variables are U238

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

ssq(acs, aeu) = 0   1 = 1

$$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := Minerr(acs, aeu)$$

$\alpha cs = 463$ $\alpha eu = 116$

Cs-137   Co-60

$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $tot_i := Cs_i + Eu_i$ $\frac{\alpha cs}{\alpha eu} = 3.991$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop.txt") := out $\frac{Eu_N}{Cs_N} = 0.033$

Borehole 22-02-01

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity
Contamination (Cs-137) from 10-20 feet is Tank Farm Activity
Contamination (Cs-137) from 40-53 feet is Stable
Contamination (Ru-106) from 55-75 feet is Stable
Contamination (Co-60 & Ru-106) from 80-96 feet is Stable

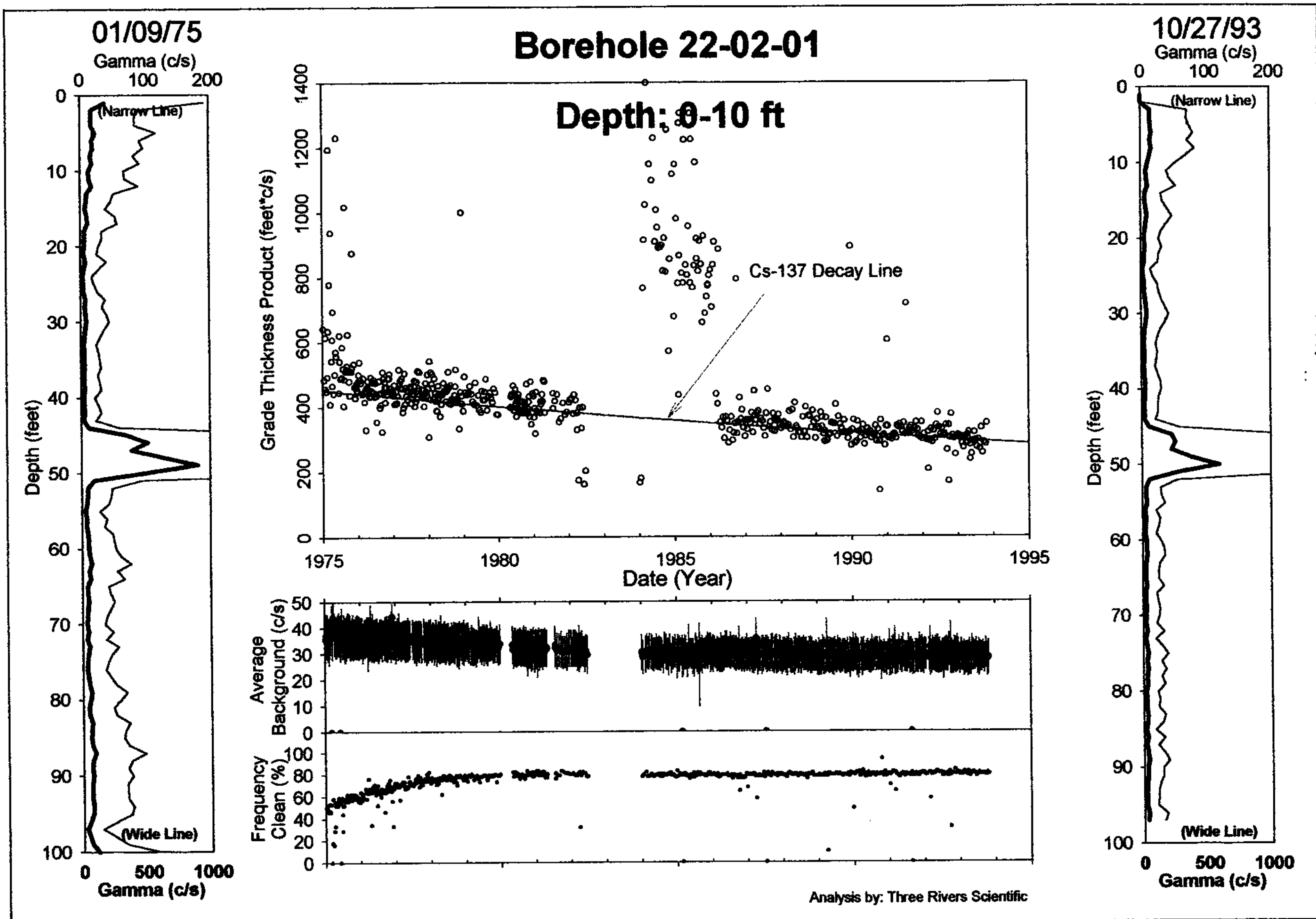
Grade thickness product, Cs-137 (HPGe identified), from 0 to 10 and 10 to 20 feet is erratic, indicative of tank farm activities such as transfer line operations. The grade thickness product appears stable from 1986 to 1993 for 0-10 feet and stable from 1984 to 1993 for 10-20 feet.
Grade thickness product from 40 to 53 feet is decreasing consistent with Cs-137 (HPGe identified) from 1975 to 1993. (Special note the possibility of Co-60 at very low levels may account for the very slight deviation from 1975 to 1983.
Grade thickness product from 55 to 75 feet is decreasing consistent with Ru-106 (hypothesis) from 1975 to 1993, but at very low levels.
Grade thickness product from 80 to 96 feet is decreasing consistent with a least squares fit for Co-60 (HPGe identified) and Ru-106 (hypothesis) from 1975 to 1993. The least squares fit results in gross gamma contribution ratio of Ru-106 to Co-60 of 2.18 as of Jan 1975.

Gross Gamma Survey Information

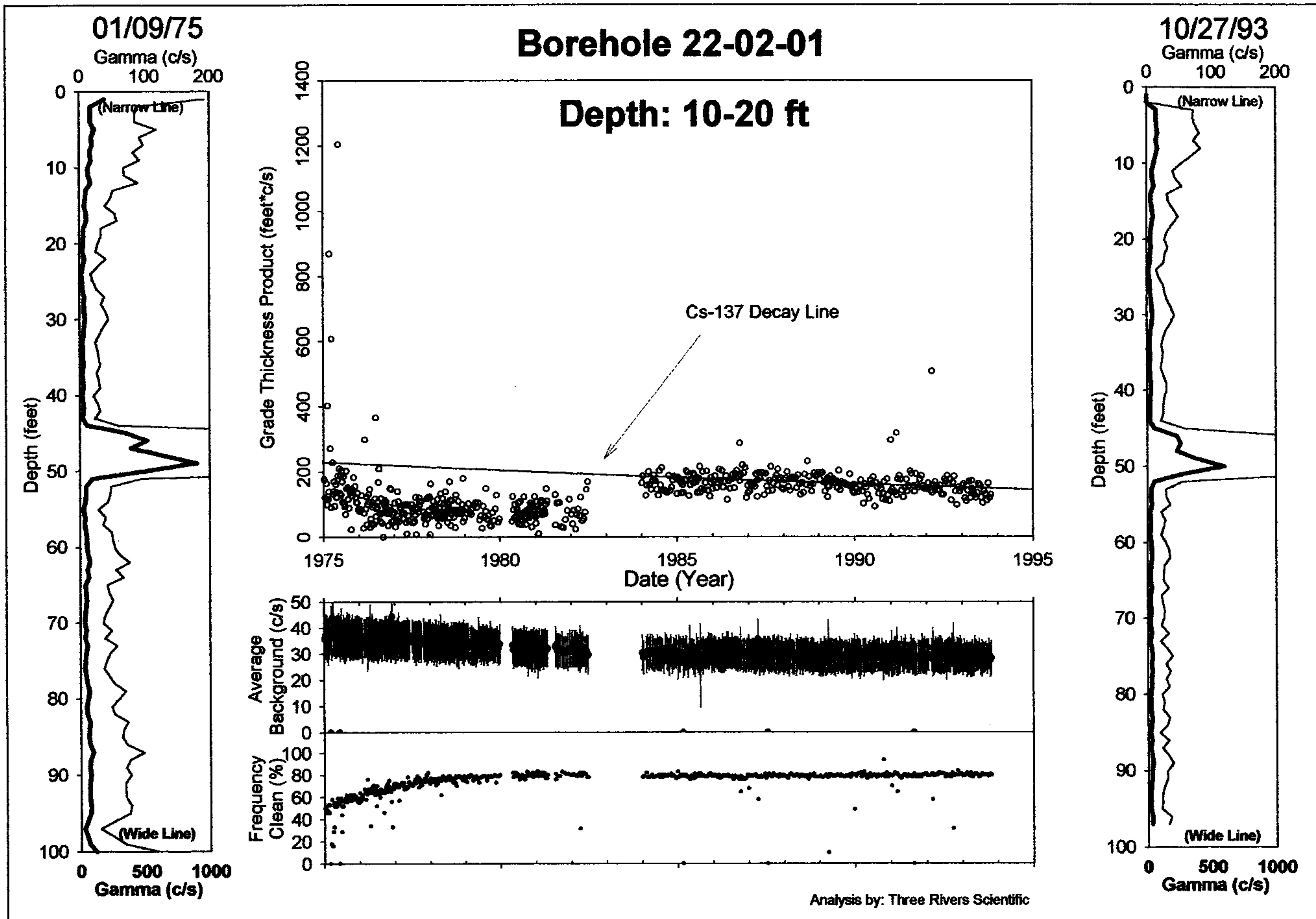
Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/9/1975
Last Survey Date :	10/27/1993
Number Surveys :	593

Analysis Notes

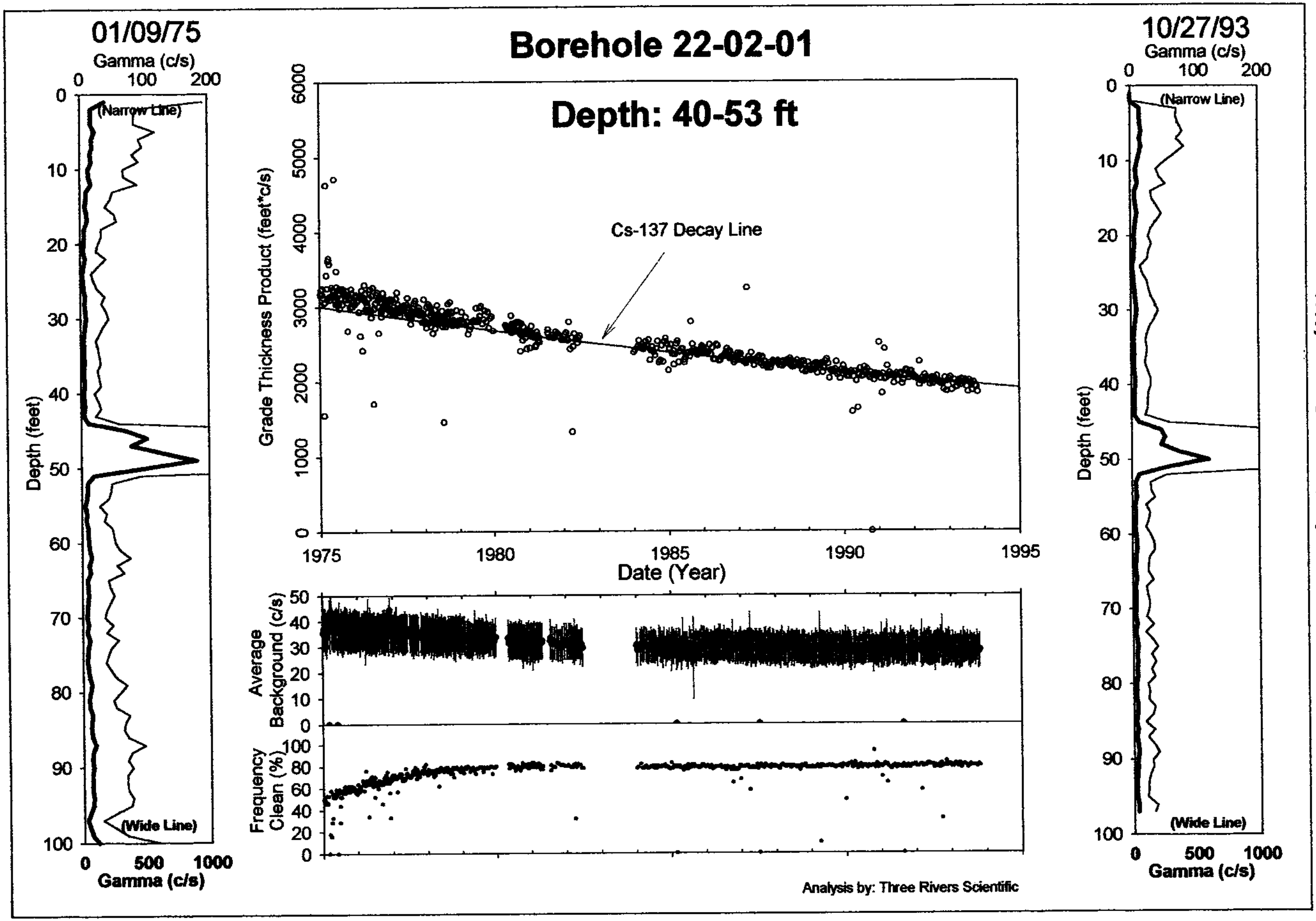
Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 & 10-20 Tank Farm Activity 40-53, 55-75, & 80-96 Stable	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	



Borehole 22-02-01
Depth: 0-10 ft
01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
10/27/93
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)

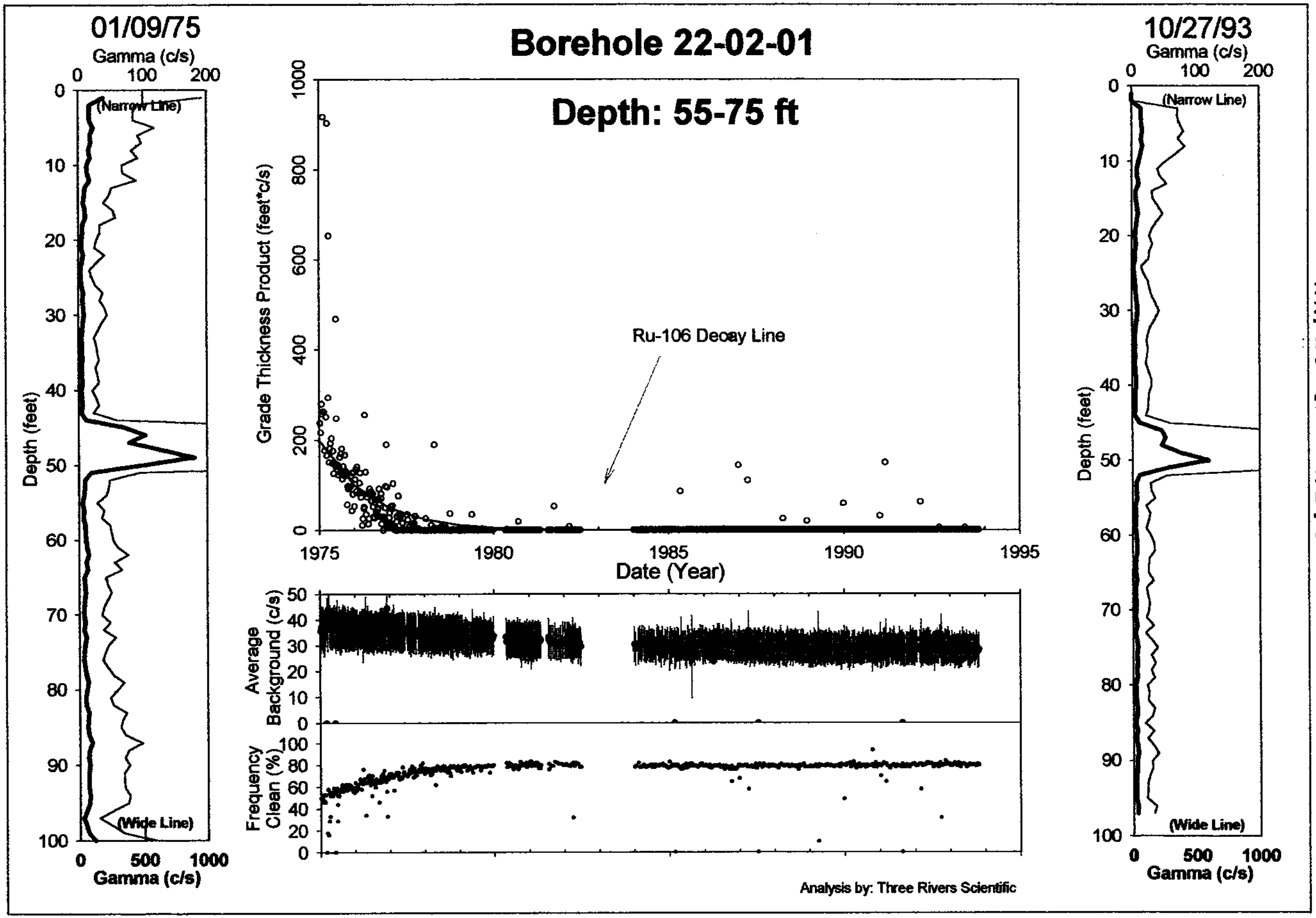


01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Borehole 22-02-01
Depth: 10-20 ft
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
10/27/93
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)

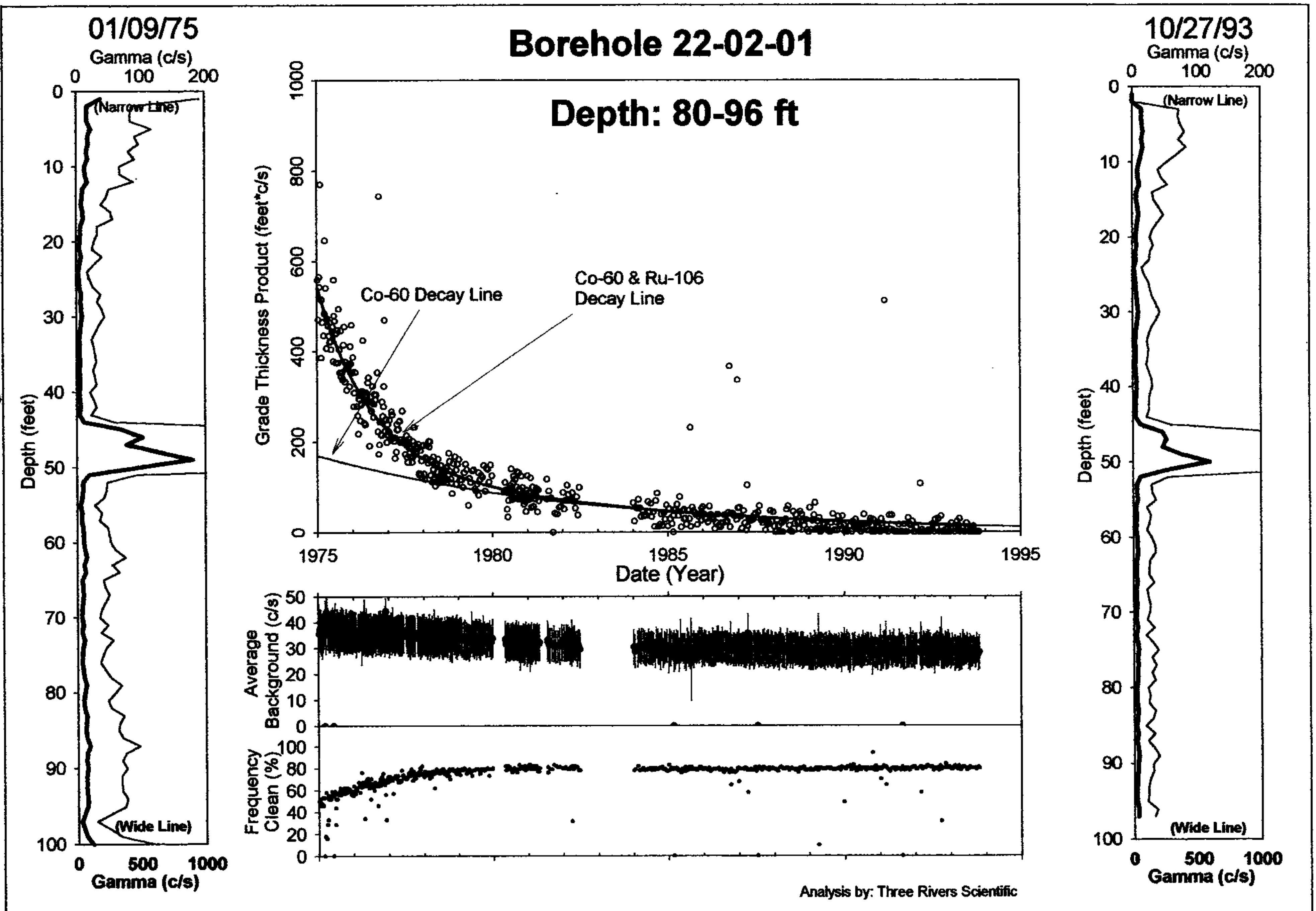


Borehole 22-02-01
Depth: 40-53 ft
01/09/75
10/27/93
Gamma (c/s)
Depth (feet)
(Narrow Line)
(Wide Line)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

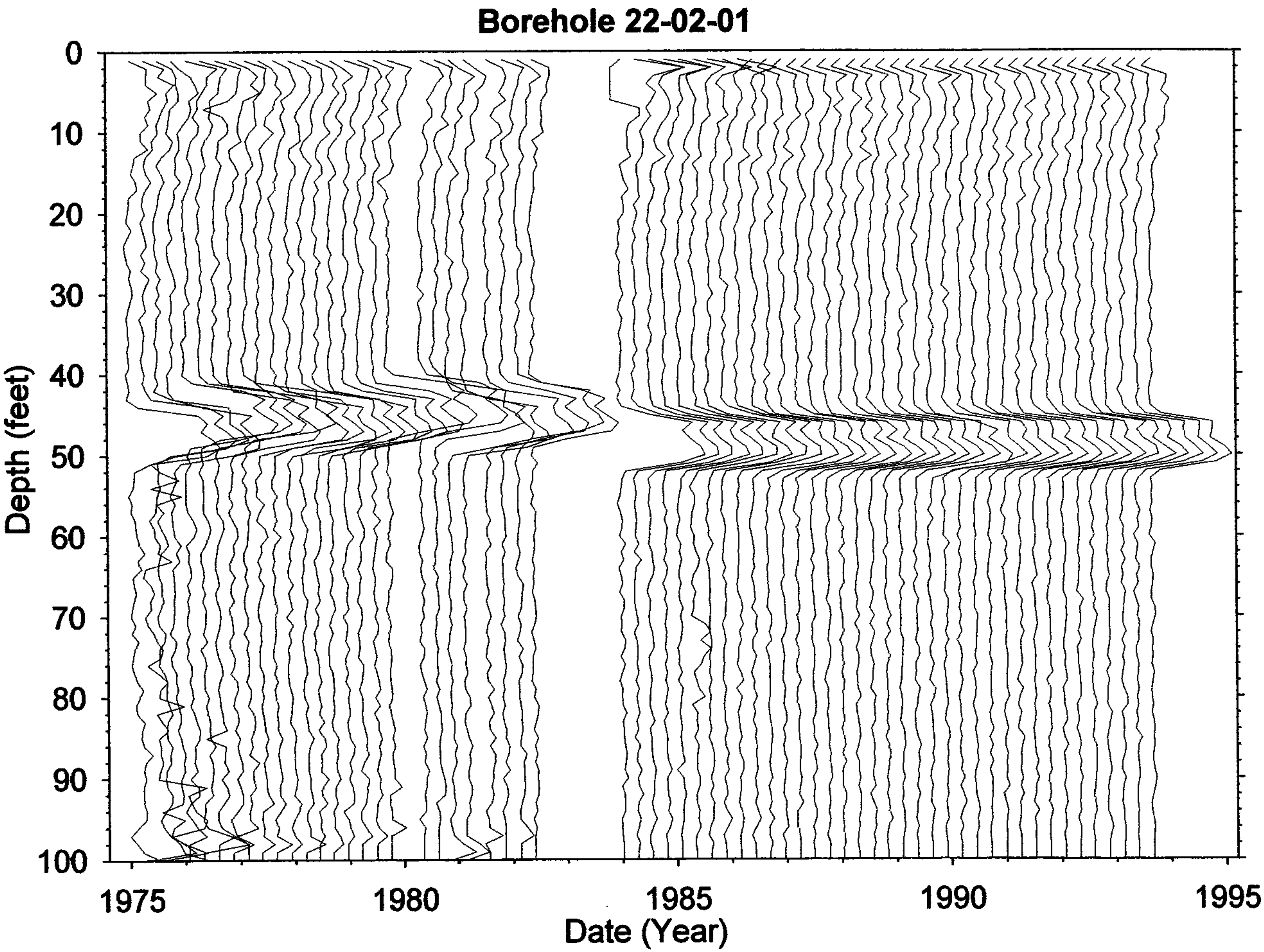
00 109



01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Borehole 22-02-01
Depth: 55-75 ft
Grade Thickness Product (feet*c/s)
Ru-106 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
10/27/93
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)



Borehole 22-02-01
Depth: 80-96 ft
01/09/75
10/27/93
Gamma (c/s)
Depth (feet)
(Narrow Line)
(Wide Line)
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Co-60 & Ru-106 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific



HNF-3532 -REV0

00 112

Borehole 22-02-02

Contamination (Cs-137) from 0-6 feet is Tank Farm Activity
Contamination (Cs-137) from 6-18 feet is Stable

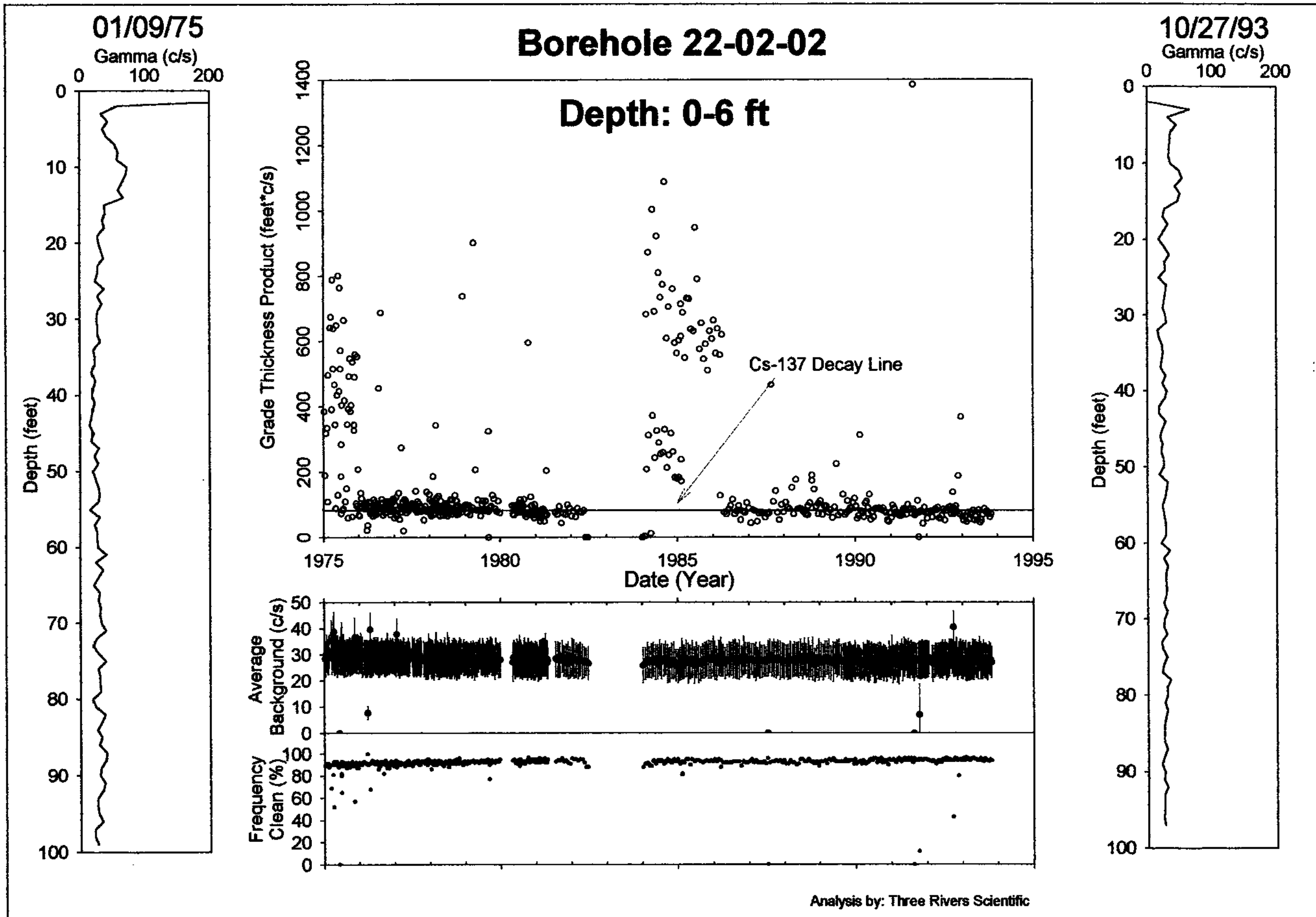
Grade thickness product from 0 to 6 feet is erratic indicative of tank farm activities such as transfer line operations.
Grade thickness product from 6 to 18 feet is decreasing consistent with Cs-137 (HPGe identified) from 1975 to 1993.

Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/9/1975
Last Survey Date :	10/27/1993
Number Surveys :	540

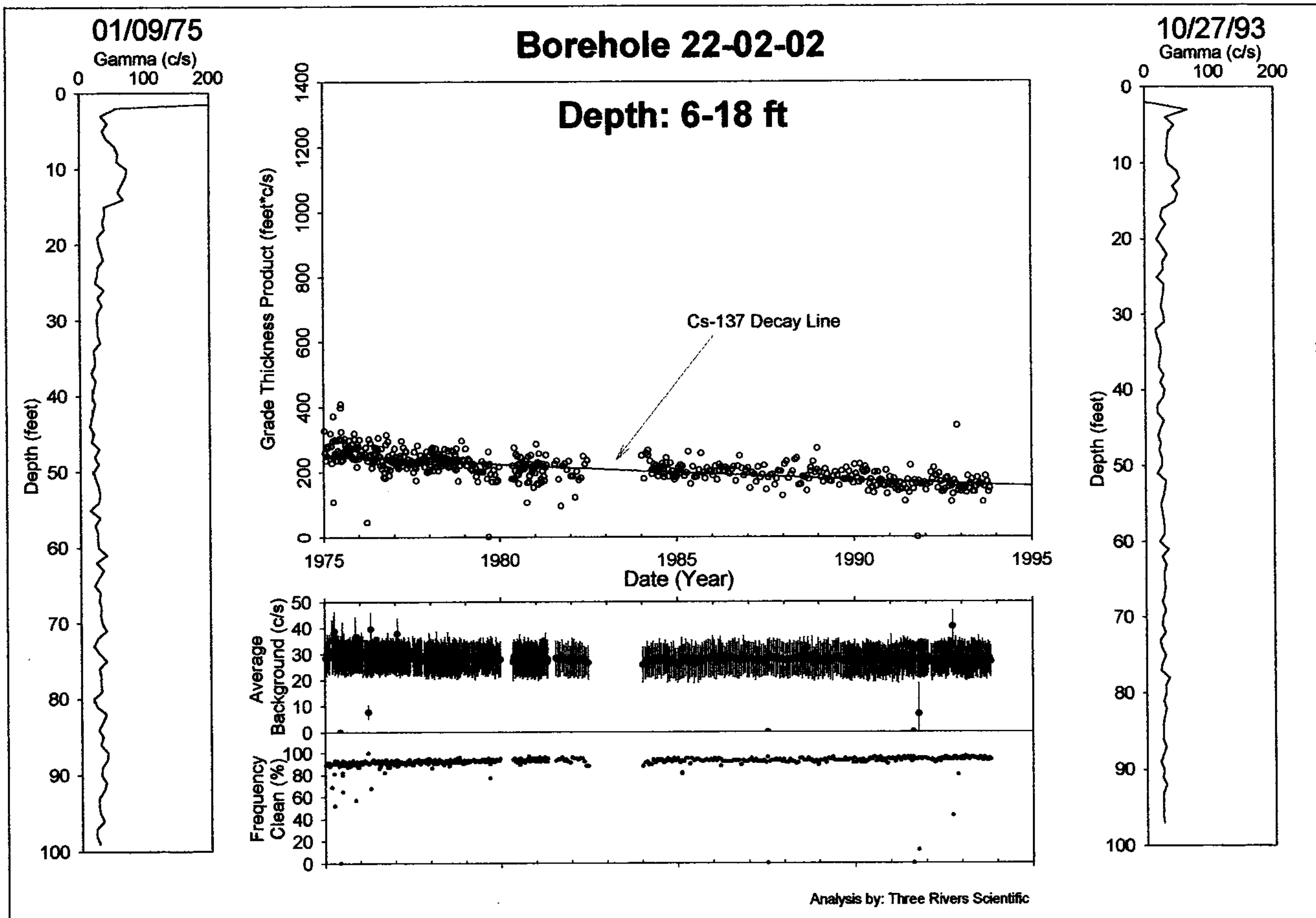
Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-6 Tank Farm Activity 6-18 Stable	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	

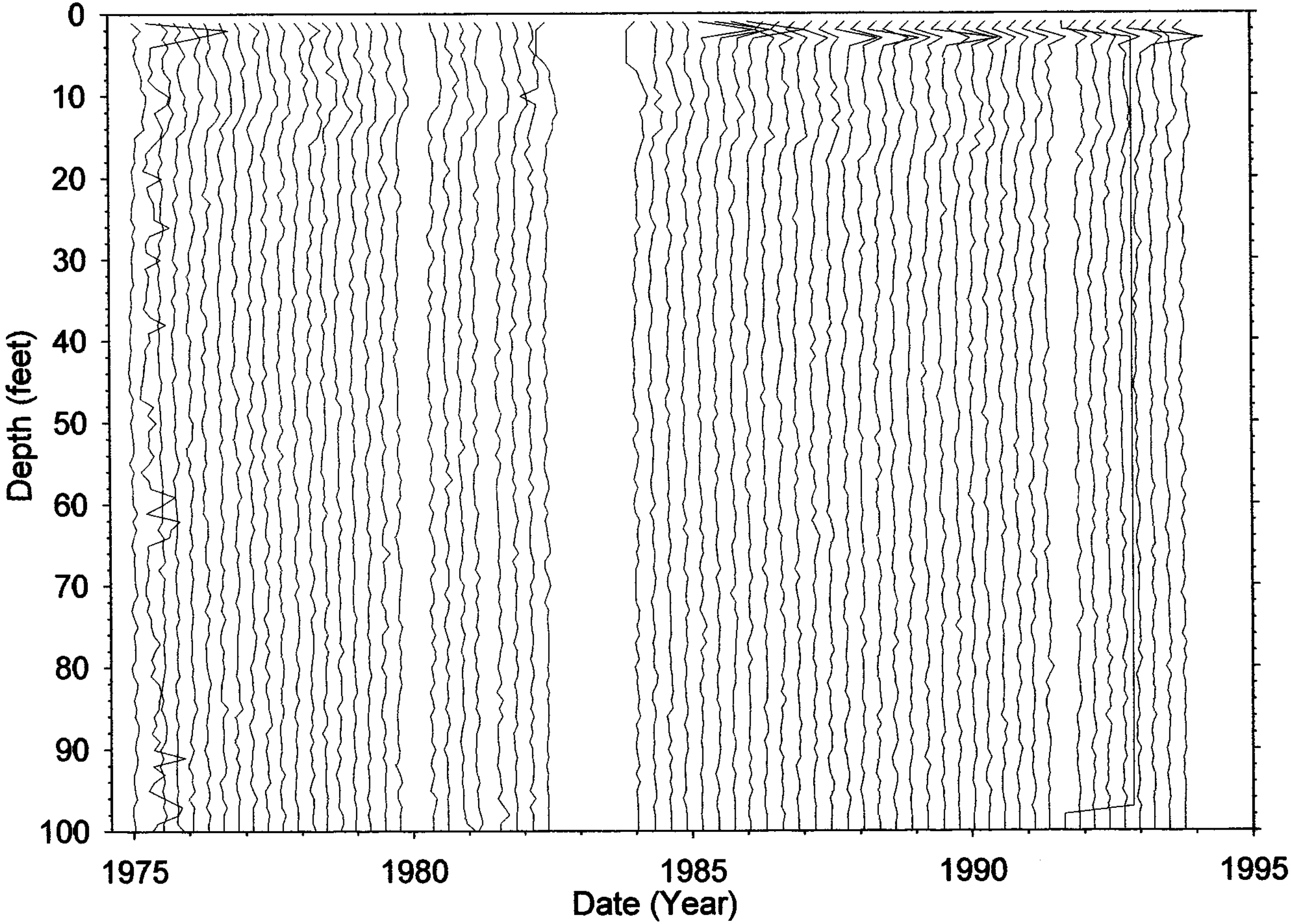


00 114

HNF-3532 -REV0


Borehole 22-02-02
Depth: 6-18 ft
01/09/75
Gamma (c/s)
Depth (feet)
10/27/93
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

Borehole 22-02-02



9116 00

HNF-3532-REV0

Borehole 22-02-05

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity

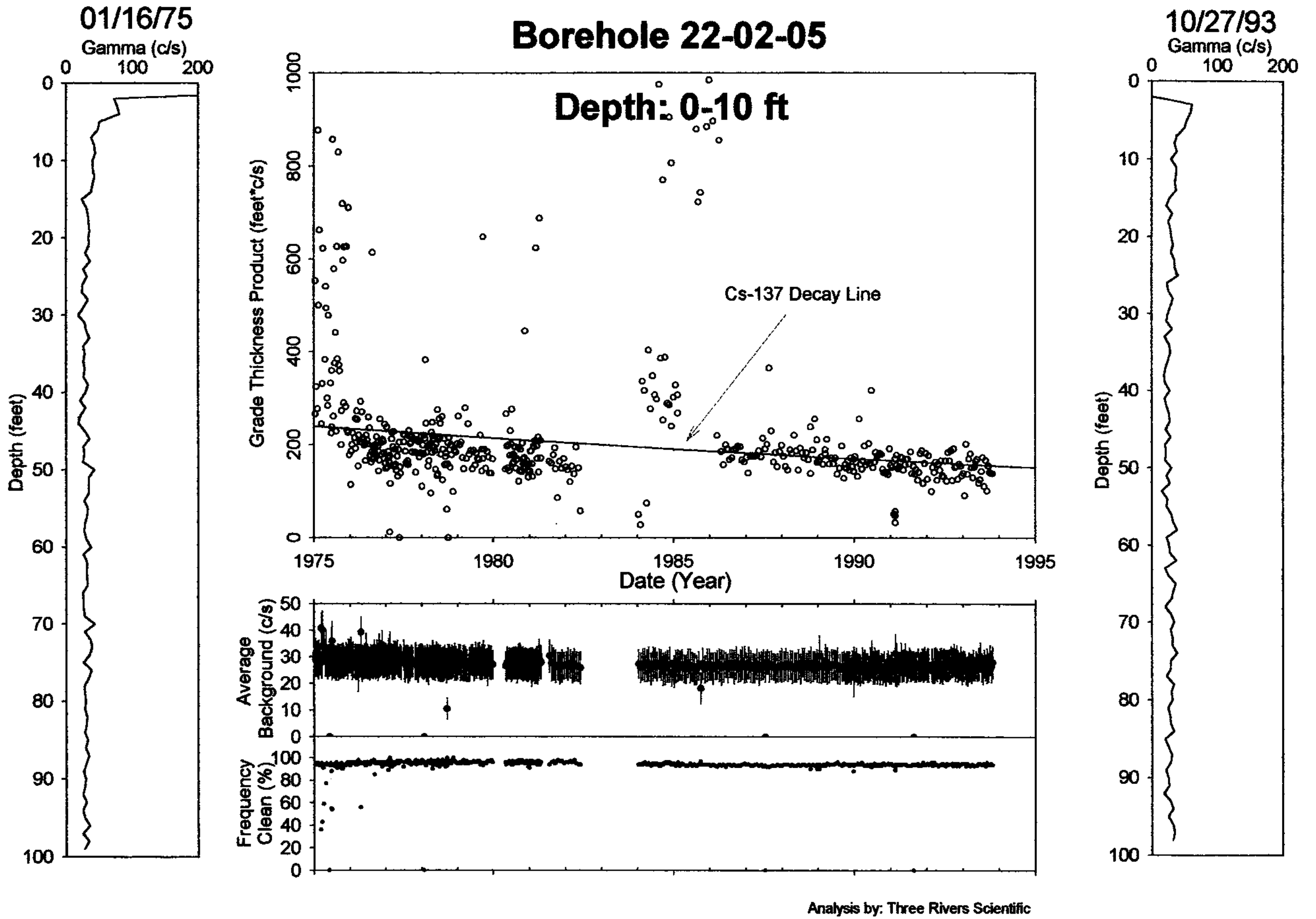
Grade thickness product from 0 to 10 feet is erratic indicative of tank farm activities such as transfer line operations.
Grade thickness product from 0 to 10 feet is decreasing consistent with Cs-137 (HPGe identified) from 1986 to 1993.

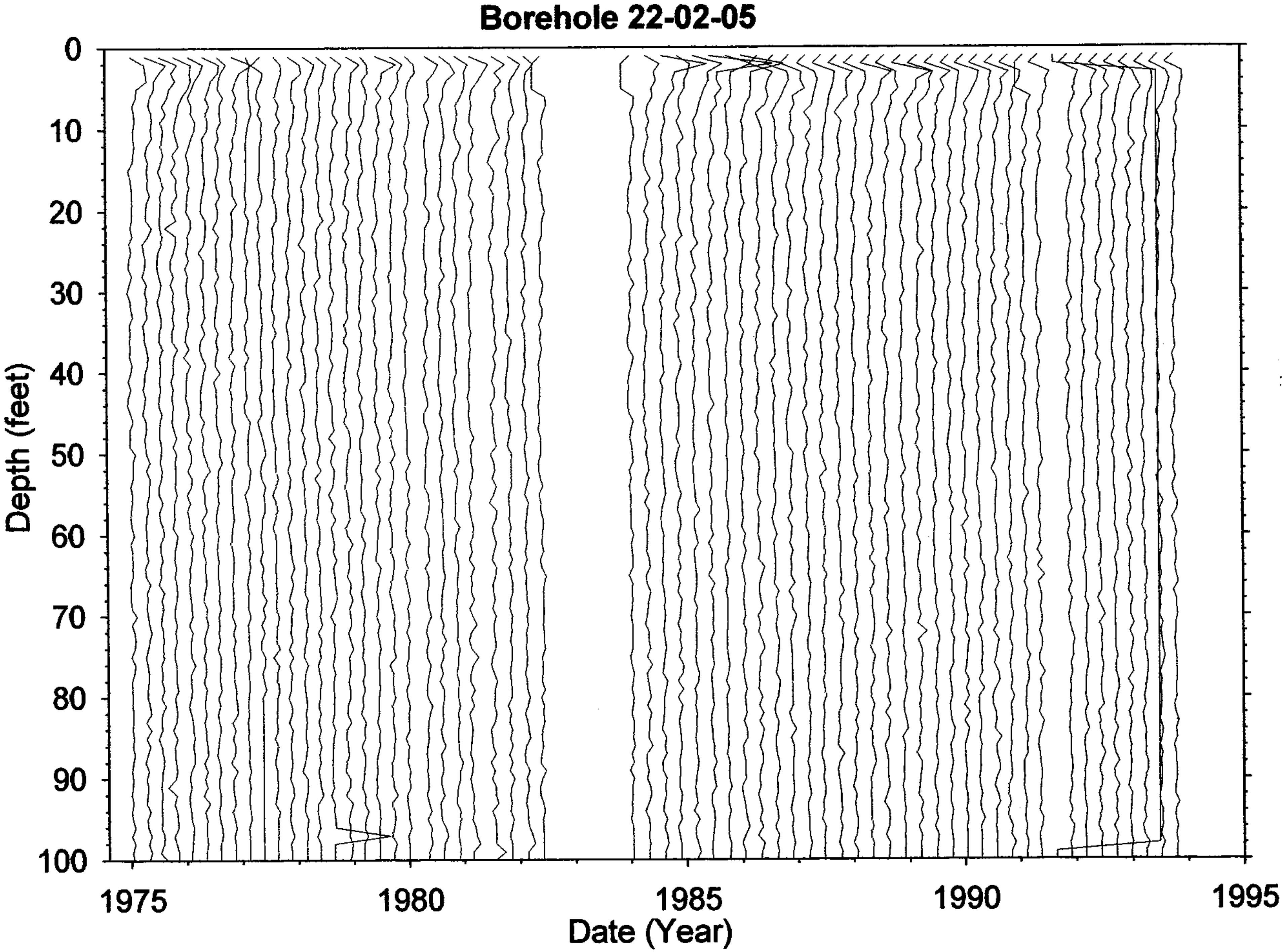
Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	02: Red GM, 03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/16/1975
Last Survey Date :	10/27/1993
Number Surveys :	545

Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 Tank Farm Activity	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	


Borehole 22-02-05
Depth: 0-10 ft
01/16/75
Gamma (c/s)
Depth (feet)
10/27/93
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Date (Year)
Cs-137 Decay Line
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific



HNF-3532 -REV0

00 119

Borehole 22-02-07

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity

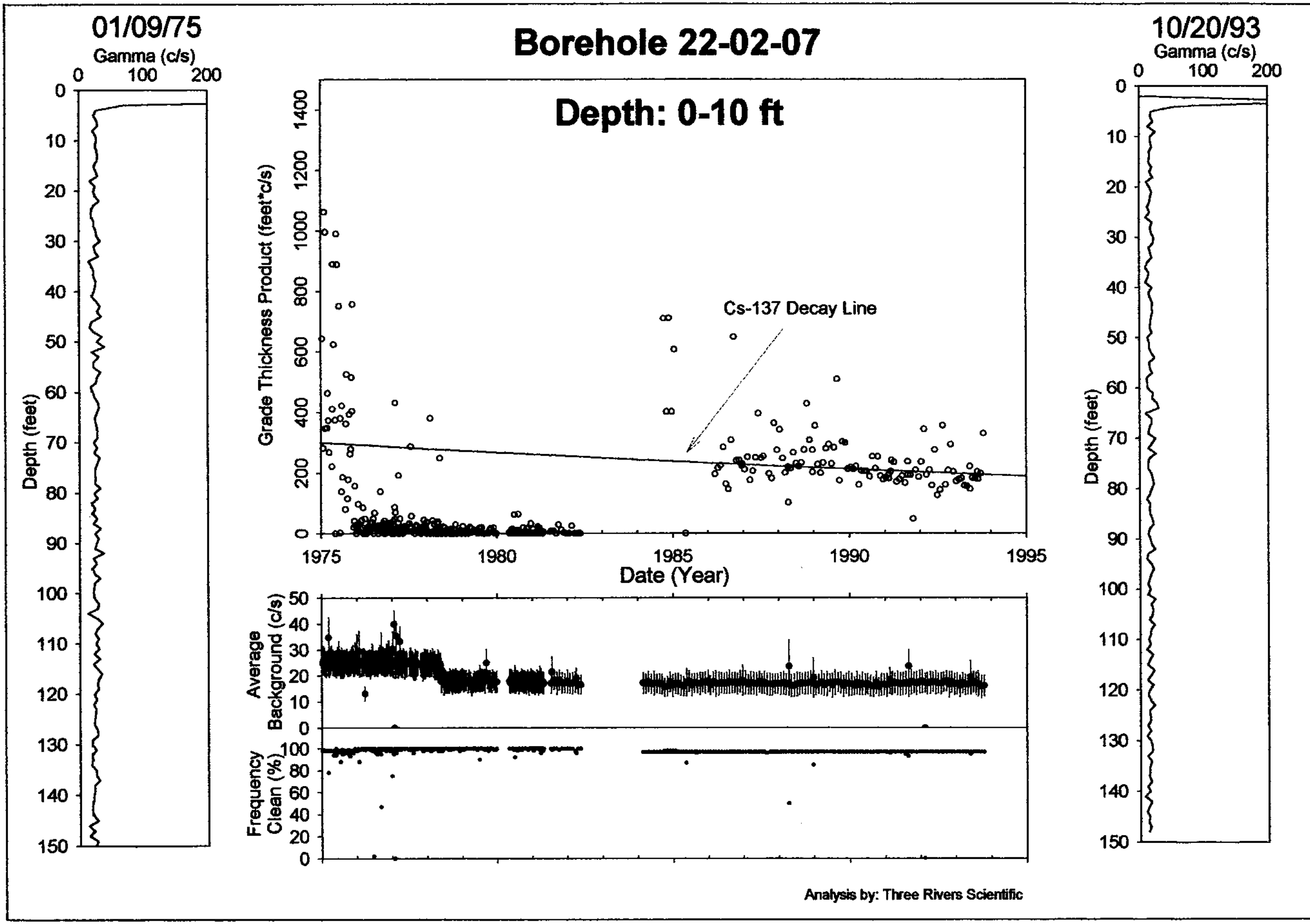
Grade thickness product from 0 to 10 feet is erratic indicative of tank farm activities such as transfer line operations.
Grade thickness product from 0 to 10 feet is decreasing consistent with Cs-137 (hypothesis, no HPGe data) from 1986 to 1993.
Special note, the average background changed consistently after May 25, 1978.

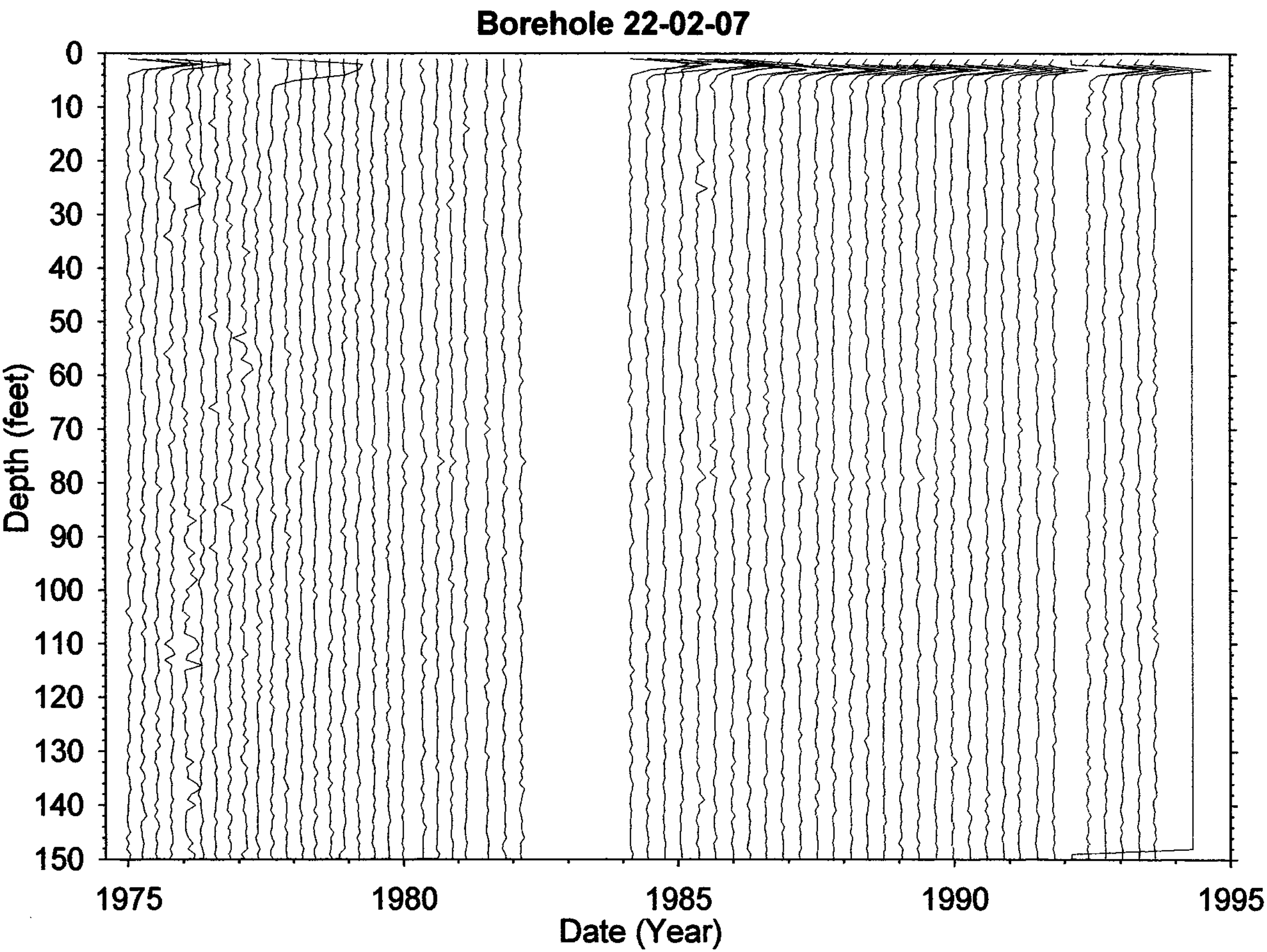
Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	150 ft
Survey Depth :	150 ft
First Survey Date :	1/9/1975
Last Survey Date :	10/20/1993
Number Surveys :	452

Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 Tank Farm Activity	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	


Borehole 22-02-07
Depth: 0-10 ft
01/09/75
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
Grade Thickness Product (feet*c/s)
0 200 400 600 800 1000 1200 1400
Cs-137 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
10/20/93
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
Analysis by: Three Rivers Scientific



HNF-3532 -REV0

00 1222

Borehole 22-02-09

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity
Contamination (Sb-125) from 20-26 feet is Stable
Contamination (Sb-125 & Ru-106) from 26-34 feet is Stable
Contamination (Sb-125 & Ru-106) from 34-44 feet is Stable
Contamination (Co-60 & Cs-137 & Ru-106) from 44-52 feet is Stable
Contamination (Co-60) from 55-65 feet is Undetermined

Grade thickness product, Cs-137 (HPGe identified), from 0 to 10 feet is erratic, indicative of tank farm activities such as transfer line operations. The grade thickness product appears stable from 1986 to 1993 for 0-10 feet.

Grade thickness product from 20 to 26 feet is decreasing consistent with Sb-125 (hypothesis) from 1975 to 1993.

Grade thickness product from 26 to 34 feet is decreasing consistent with a least squares fit for Sb-125 (hypothesis) and Ru-106 (hypothesis) from 1975 to 1993. The least squares fit results in gross gamma contribution ratio of Ru-106 to Sb-125 of 5.34 as of Jan 1975. Note, Cs-137 HPGe identified, but at low enough levels to not register above threshold.

Grade thickness product from 34 to 44 feet is decreasing consistent with a least squares fit for Sb-125 (hypothesis) and Ru-106 (hypothesis) from 1975 to 1993. The least squares fit results in gross gamma contribution ratio of Ru-106 to Sb-125 of 0.19 as of Jan 1975. Note, Cs-137 HPGe identified, but at low enough levels to not register above threshold.

Grade thickness product from 44 to 52 feet is decreasing consistent with a least squares fit for Ru-106 (hypothesis) and Co-60 (HPGe identified) and Cs-137 (HPGe identified) from 1975 to 1993. The least squares fit results in gross gamma contribution ratio of Ru-106:Co-60:Cs-137 of 1780:613:106 as of Jan 1975.

Grade thickness product from 55 to 65 feet is decreasing consistent with Co-60 (HPGe identified) from 1975 to 1993, but at very low levels. There may be some indication of Ru-106 at low levels very early (1975-1976), but such a short time cannot be used to differentiate stable from a hypothesis fit.

Borehole 22-02-09

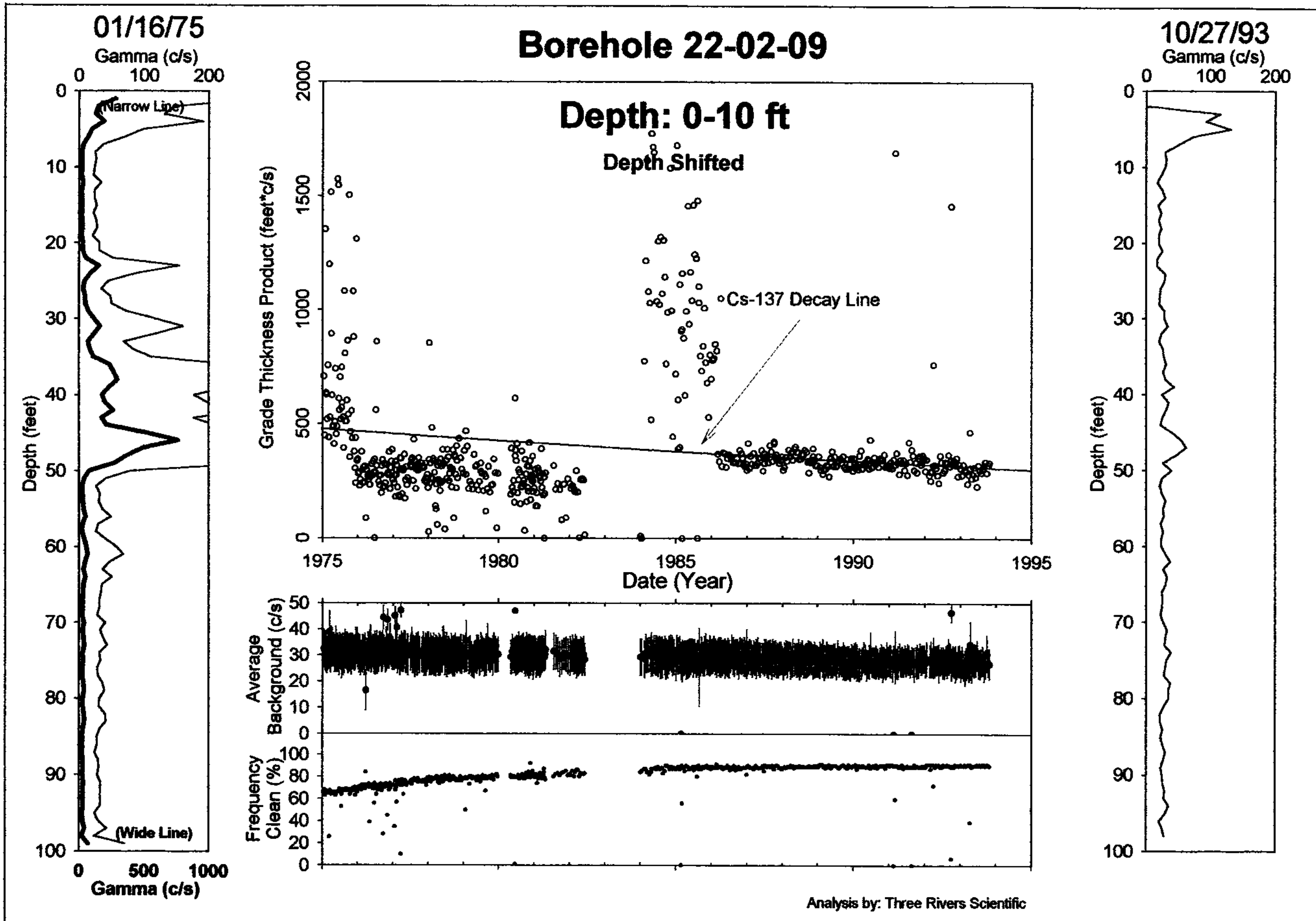
Page 2 of 2

Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/16/1975
Last Survey Date :	10/27/1993
Number Surveys :	607

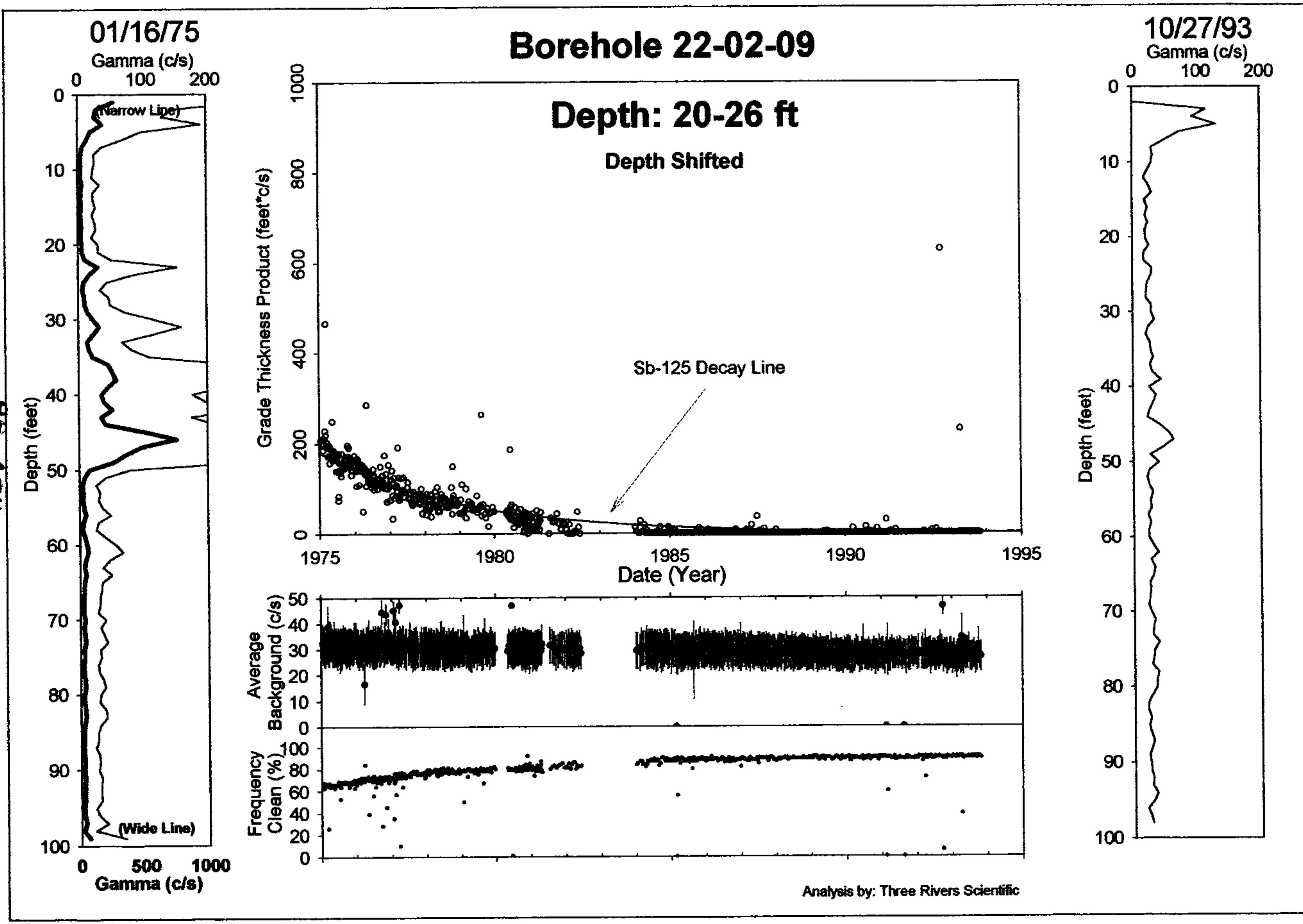
Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 Tank Farm Activity, 20-26, 26-34, 34-44, & 44-52 Stable, 55-65 Undetermined	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	



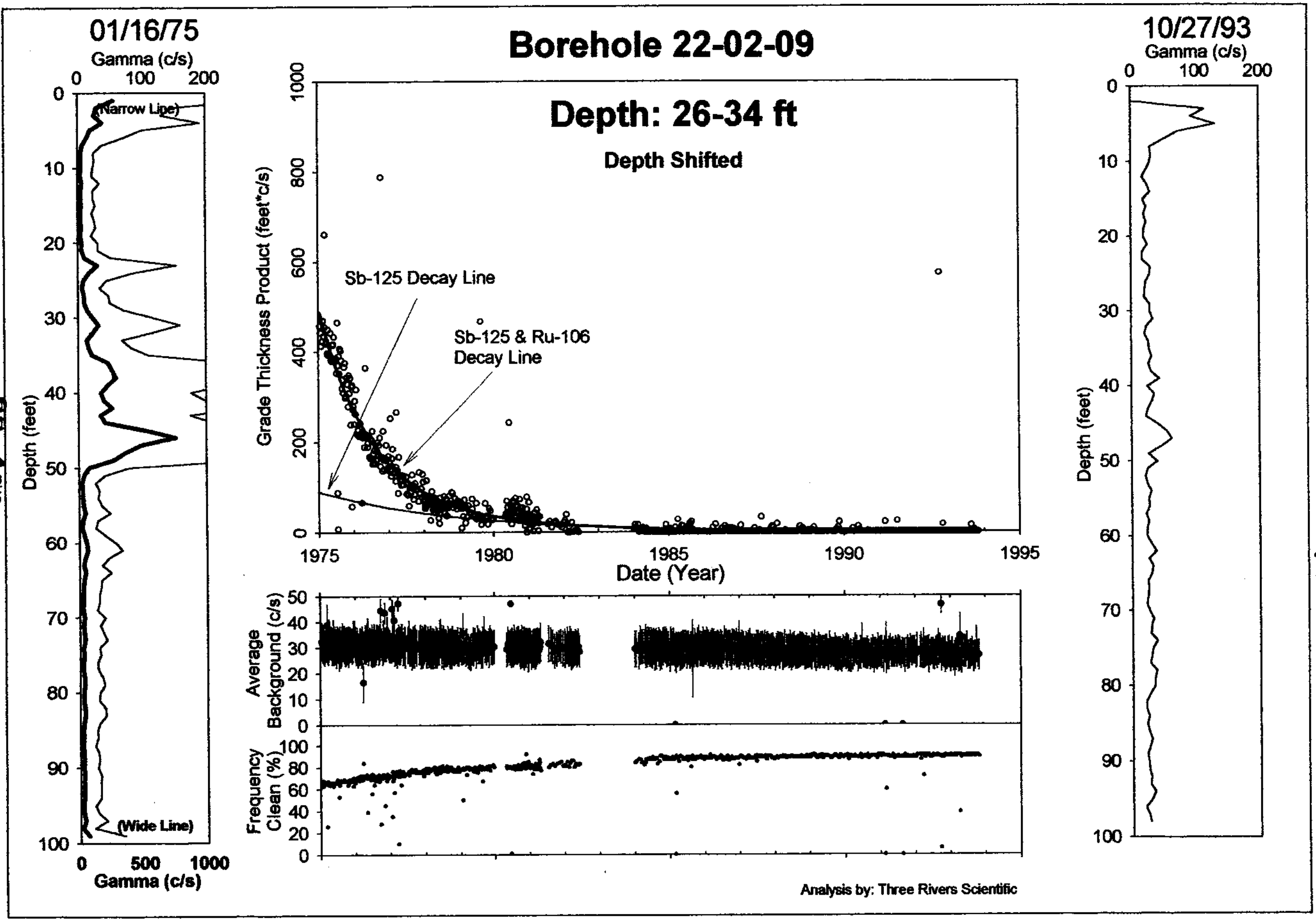
01/16/75
Gamma (c/s)
0
100
200
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
(Narrow Line)
(Wide Line)
0
500
1000
Gamma (c/s)
Borehole 22-02-09
Depth: 0-10 ft
Depth Shifted
Grade Thickness Product (feet*c/s)
0
500
1000
1500
2000
Cs-137 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average Background (c/s)
0
10
20
30
40
50
Frequency Clean (%)
0
20
40
60
80
100
Analysis by: Three Rivers Scientific
10/27/93
Gamma (c/s)
0
100
200
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100

00 125



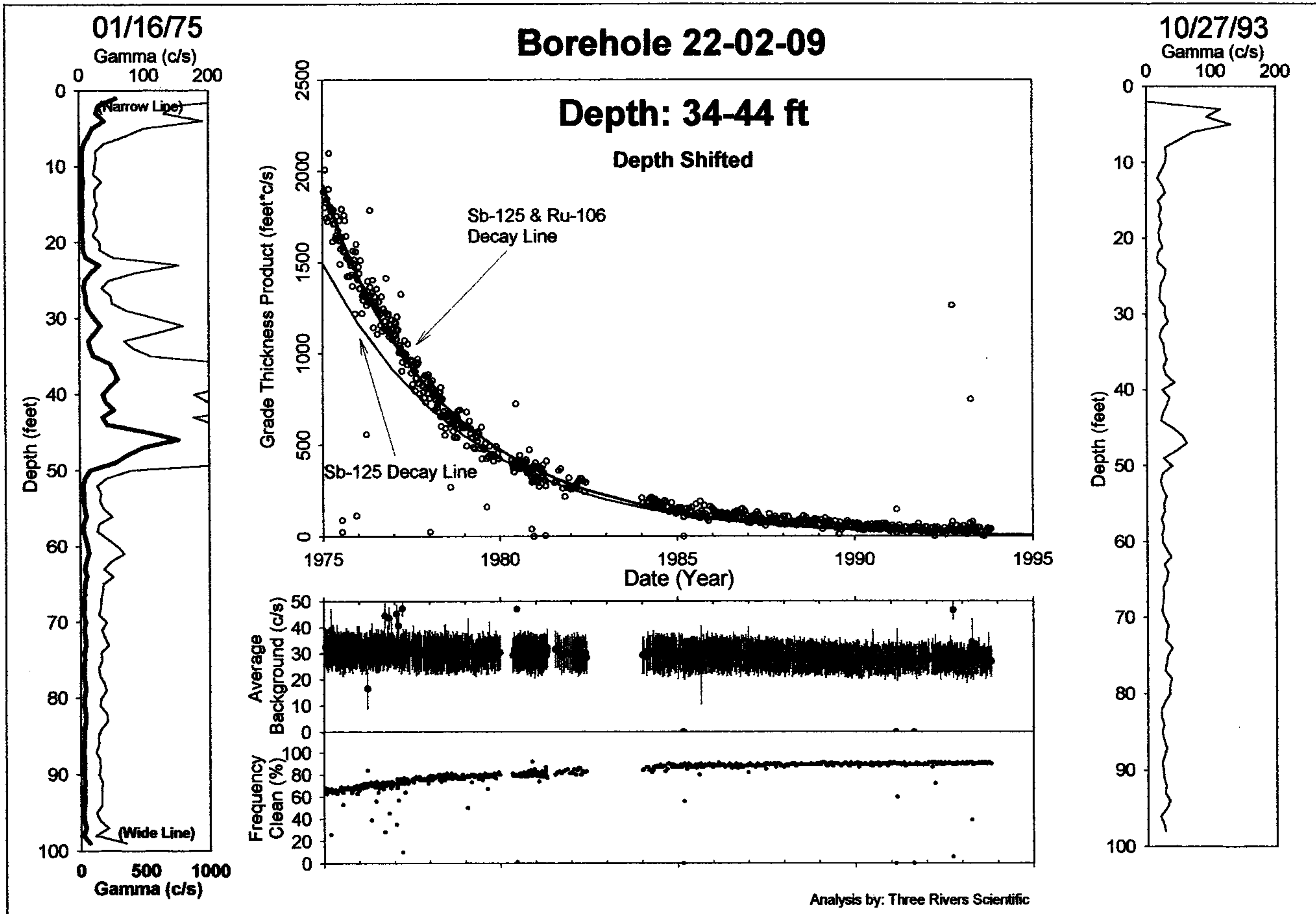
01/16/75
Gamma (c/s)
0 100 200
(Narrow Line)
(Wide Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
0 500 1000
Gamma (c/s)
Borehole 22-02-09
Depth: 20-26 ft
Depth Shifted
Grade Thickness Product (feet*c/s)
0 200 400 600 800 1000
Sb-125 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
10/27/93
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100

00 126



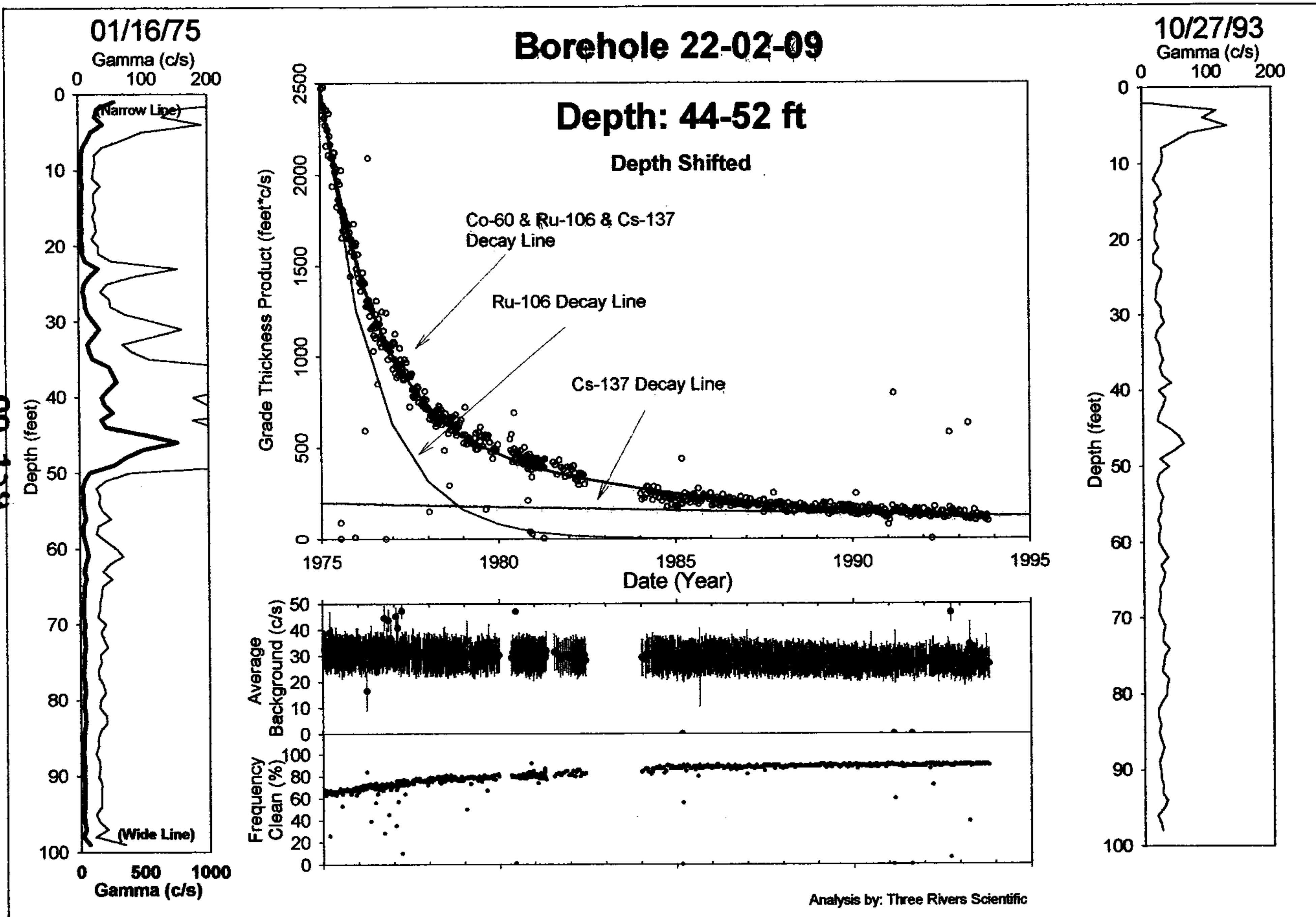
00 127

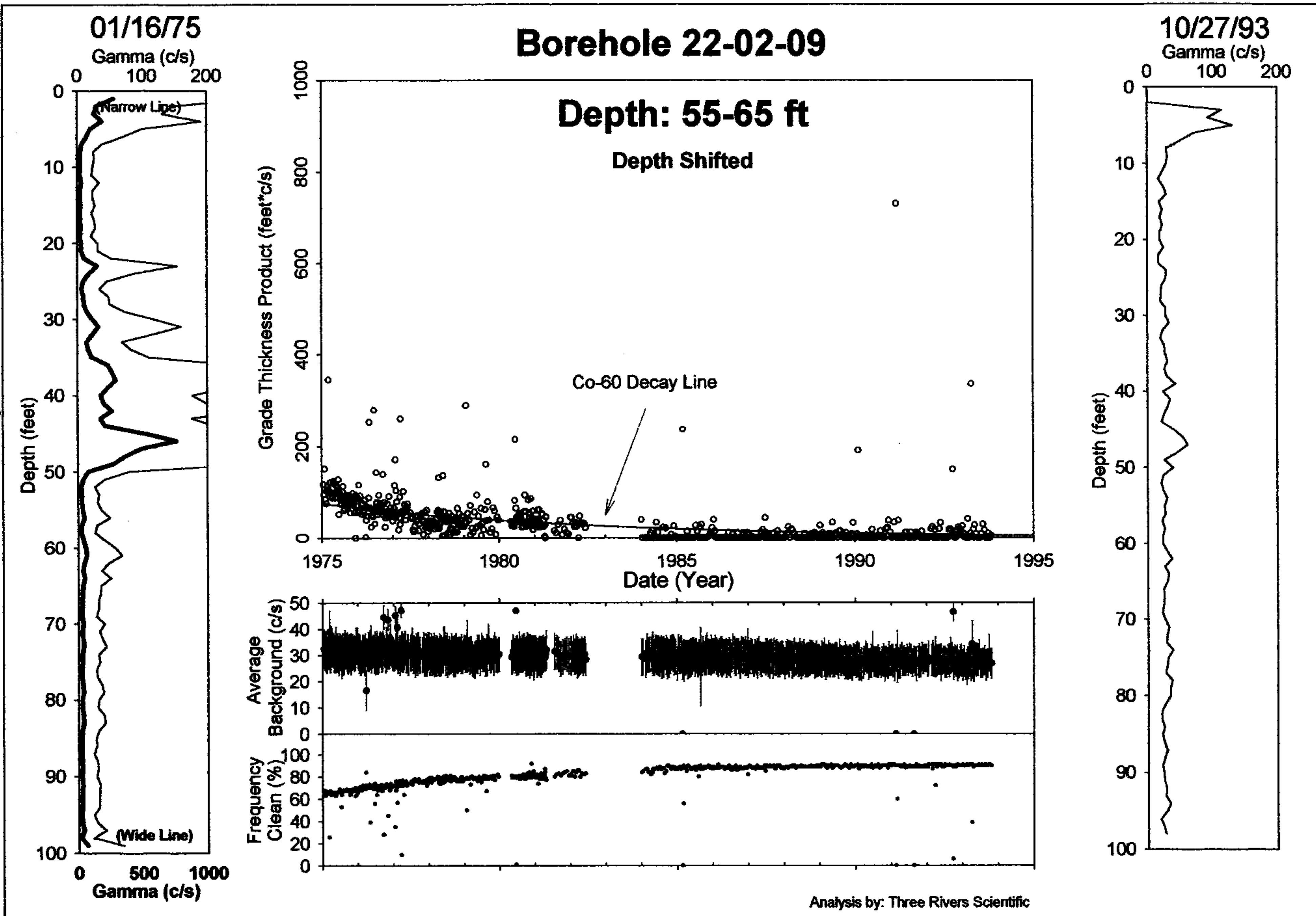
HNF-3532 -REV0



00 128

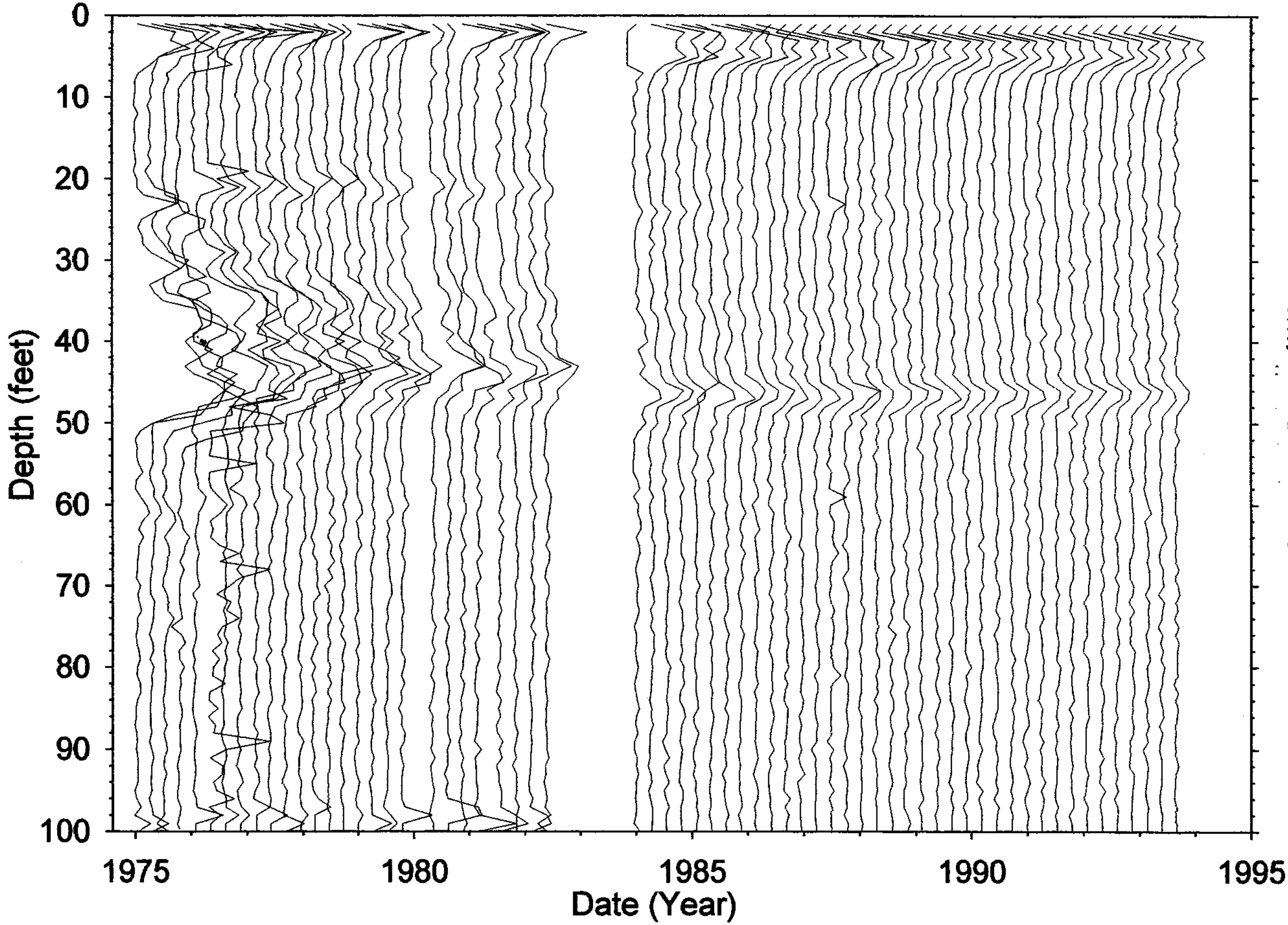
HNF-3532 -REV0


Borehole 22-02-09
Depth: 44-52 ft
Depth Shifted
01/16/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Co-60 & Ru-106 & Cs-137
Decay Line
Ru-106 Decay Line
Cs-137 Decay Line
Date (Year)
Average
Background (c/s)
Frequency
Clean (%)
Analysis by: Three Rivers Scientific
10/27/93
Gamma (c/s)
Depth (feet)

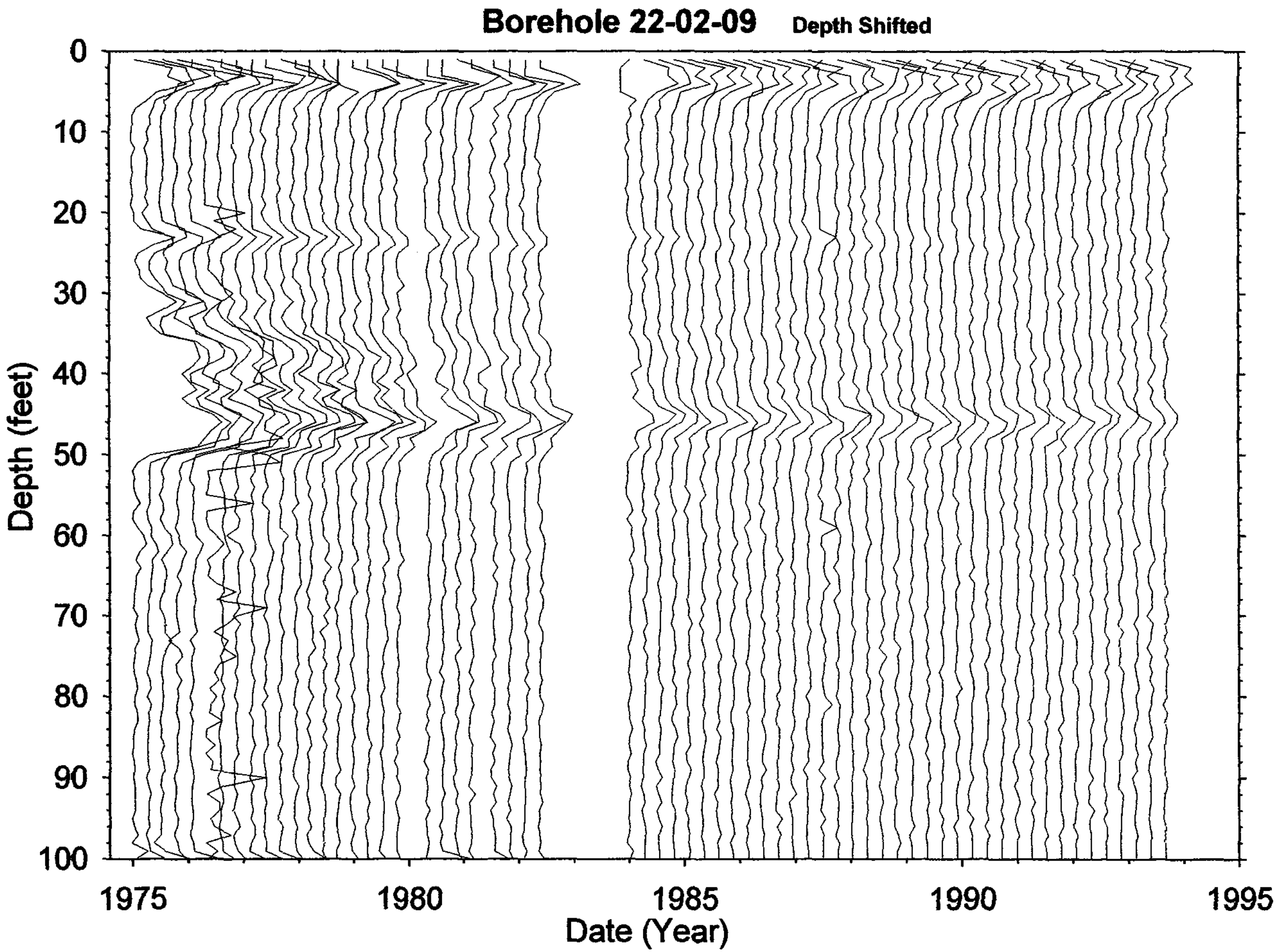


01/16/75
Gamma (c/s)
0
100
200
(Narrow Line)
(Wide Line)
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
0
500
1000
Gamma (c/s)
Borehole 22-02-09
Depth: 55-65 ft
Depth Shifted
Grade Thickness Product (feet*c/s)
0
200
400
600
800
1000
Co-60 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average
Background (c/s)
0
10
20
30
40
50
Frequency
Clean (%)
0
20
40
60
80
100
Analysis by: Three Rivers Scientific
10/27/93
Gamma (c/s)
0
100
200
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100

Borehole 22-02-09



HNF-3532-REV0



HNF-3532 - REV0

00 132

BY

Dry Well Survey Analysis - Notes

Borehole 22-02-01 Total # Surveys 602 Probe Type 04

\# neutron surveys 9 # GR Surveys 593

Log Date: 1-9-75 1st 10-27-93 Last Presentation Plot Dates

(If different from 1st & Last)

Contamination Zone Depth(s):

Isotope from Spectral Survey: Cs & Co days & Ru Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

$\underbrace{\text{0-10 \quad 10-20 \quad 40-53}}_{\text{Cs}}$ 80-96

Cs + Ru

55-75 → Ru

Analyst Name [signature] S/W ver TFGROSS 2.2

filein := "two.txt"

Well 21-02-01

A := READPRN(filein)
80-96 feet

$yr := A^{\langle 1\rangle}$ $net := A^{\langle 7\rangle}$ $bkg := A^{\langle 6\rangle}$ $max := A^{\langle 4\rangle}$

$N := last(yr)$ $N = 515$ $i := 0..N$ $k := 0..300$ $j := 0..299$ $\tau eu := 1$

$\tau co := 5.27$ $\tau cs := 5.27$ $aco := 00$ $acs := 172$

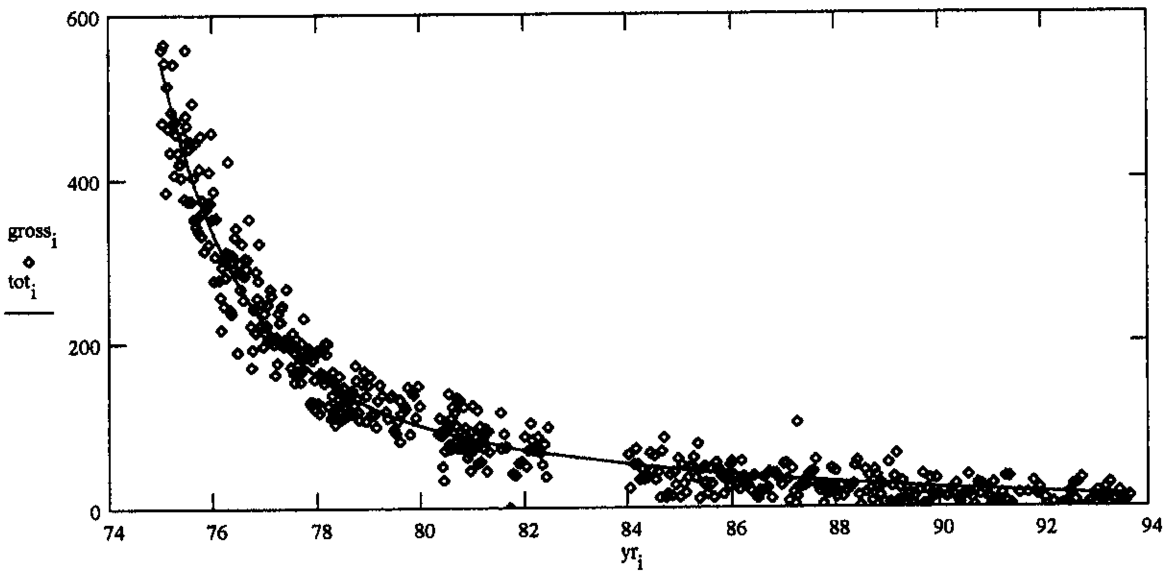
Eu variables are
Ru-106 $aeu := 375$

$Cs_i := acs\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}\cdot 1$ $tot_i := Cs_i + Eu_i$

Cs variables are Co-60

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}\right]\right]^2$$

Given

$ssq(acs,aeu) = 0$ $1 = 1$

$$\begin{bmatrix}\alpha cs\\ \alpha eu\end{bmatrix} := Minerr(acs,aeu)$$

$\alpha cs = 172.836$
Co-60

$\alpha eu = 375.357$
Ru-106

$\frac{\alpha cs}{\alpha eu} = 0.46$

$Cs_i := \alpha cs\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $tot_i := Cs_i + Eu_i$

$\frac{Eu_N}{Cs_N} = 6.068\cdot 10^{-5}$

$out^{\langle 0\rangle} := yr$ $out^{\langle 1\rangle} := tot$ WRITEPRN("twop.txt") := out

Dry Well Survey Analysis - Notes

BY

Borehole 22-02-02 Total # Surveys 545 Probe Type 04

\# neutron surveys 5 # GR Surveys 540

Log Date: 1-9-75 1st 10-27-93 Last Presentation Plot Dates ______

(If different from 1st & Last)

Contamination Zone Depth(s): ______

Isotope from Spectral Survey: Cs @ surface Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			A surface & a shallow Cs 7-18 ft
			from Stack 0-6 & 6-18

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Analyst Name Roger Randall S/W ver TFGR0552.2

Dry Well Survey Analysis - Notes

BY

Borehole 22-02-05 Total # Surveys 549 Probe Type 04 02
neutron surveys 3 # GR Surveys 545
Log Date: 1-16-75 1st 10-27-93 Last Presentation Plot Dates
(If different from 1st & Last)

Contamination Zone Depth(s): 0-10
Isotope from Spectral Survey: Cs most @ any Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			0-10 ft hga show
			& erratic

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Analyst Name Bruce Randall S/W ver TFGROSS2.2

Dry Well Survey Analysis - Notes

Borehole 22-02-07 Total # Surveys 454 Probe Type D4

\# neutron surveys 2 # GR Surveys 452

Log Date: 1-9-75 1st 10-20-93 Last Presentation Plot Dates ______ (If different from 1st & Last)

Contamination Zone Depth(s): 0-10

Isotope from Spectral Survey: no log Max Survey Depth 150

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			0-10 erratic shows

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

The average background changed mid 75 ?
this is only well so far

Analyst Name Russ Randall S/W ver TFGRAFF 2.2

Dry Well Survey Analysis - Notes

Borehole 22-02-09 Total # Surveys 610 Probe Type 04
\# neutron surveys 3 # GR Surveys 607
Log Date: 1-16-75 1st 10-27-93 Last Presentation Plot Dates ________
(If different from 1st & Last)

Contamination Zone Depth(s): ________
Isotope from Spectral Survey: Cs & Co Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			0-10 shows peak @ 22
			28-52 broad zone
			peak @ 60 dies out

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

0-10 all after depth shift
20-26
26-34
34-44
44-52
55-65

Analyst Name Russ Randall S/W ver TFGROSS 2.2

filein := "two26-34.txt" **Well 21-02-09**

A := READPRN(filein) $yr := A^{\langle 1 \rangle}$ $net := A^{\langle 7 \rangle}$ $bkg := A^{\langle 6 \rangle}$ $max := A^{\langle 4 \rangle}$

N := last(yr) N = 577 i := 0..N k := 0..300 j := 0..299 $\tau eu := 1$

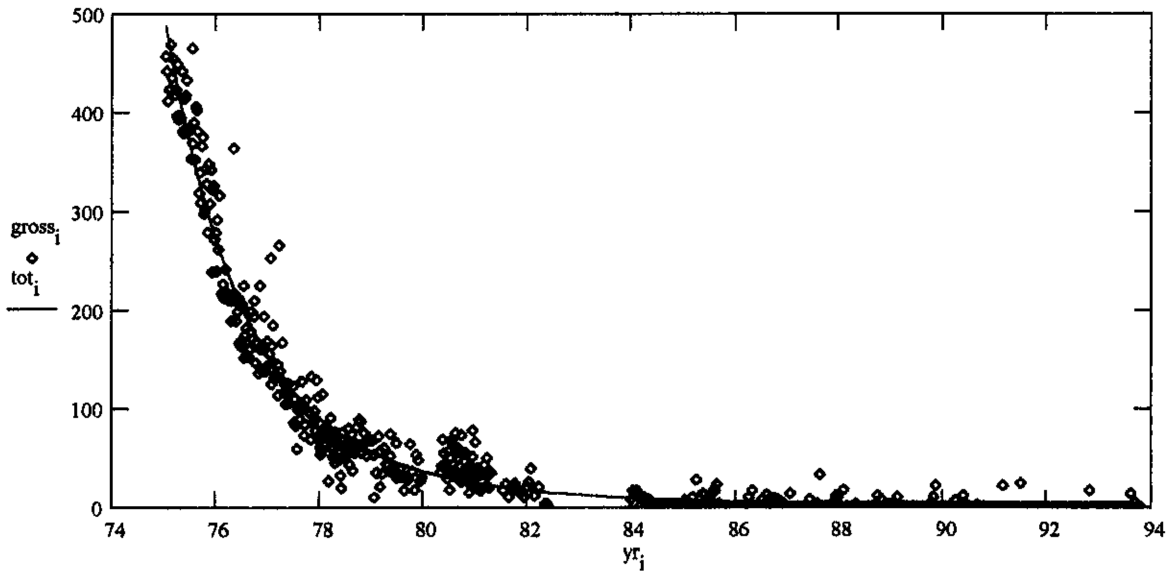
$\tau co := 5.27$ $\tau cs := 2.77$ aco := 00 acs := 82 Eu variables are Ru-106 aeu := 419

$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1$ $tot_i := Cs_i + Eu_i$

$gross_i := net_i$

Cs variables are Sb-125

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}\right]\right]^2$$

Given

ssq(acs, aeu) = 0 1 = 1

$$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := Minerr(acs, aeu)$$

$\alpha cs = 79.253$ Sb-125 $\alpha eu = 423.444$ Ru-106

$\frac{\alpha cs}{\alpha eu} = 0.187$

$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $tot_i := Cs_i + Eu_i$

$out^{\langle 0 \rangle} := yr$ $out^{\langle 1 \rangle} := tot$ WRITEPRN("twop26-34.txt") := out $\frac{Eu_N}{Cs_N} = 1.279 \cdot 10^{-3}$

filein := "two34-44.txt" **Well 21-02-09**

$A := \mathrm{READPRN}(\mathrm{filein})$ $\quad yr := A^{\langle 1 \rangle}$ $\quad net := A^{\langle 7 \rangle}$ $\quad bkg := A^{\langle 6 \rangle}$ $\quad max := A^{\langle 4 \rangle}$

$N := \mathrm{last}(yr)$ $\quad N = 586$ $\quad i := 0..N$ $\quad k := 0..300$ $\quad j := 0..299$ $\quad \tau eu := 1$

$\tau co := 5.27$ $\quad \tau cs := 2.77$ $\quad aco := 00$ $\quad acs := 1630$

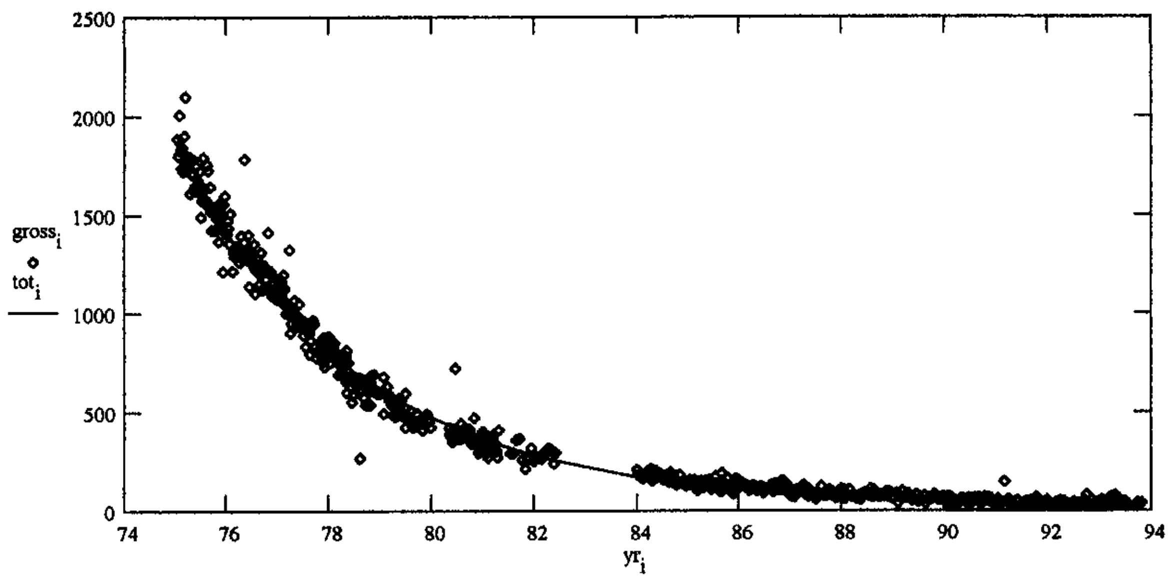
Eu variables are Ru-106 $\quad aeu := 300$

$$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \qquad Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \qquad Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1 \qquad tot_i := Cs_i + Eu_i$$

$gross_i := net_i$

Cs variables are Sb-125

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

$ssq(acs, aeu) = 0 \qquad 1 = 1$

$$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := \mathrm{Minerr}(acs, aeu)$$

$\alpha cs = 1.637 \cdot 10^3$ Sb-125 $\qquad \alpha eu = 311.536$ Ru-106

$$\frac{\alpha cs}{\alpha eu} = 5.255$$

$$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \qquad Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \qquad tot_i := Cs_i + Eu_i$$

$out^{\langle 0 \rangle} := yr \qquad out^{\langle 1 \rangle} := tot \qquad \mathrm{WRITEPRN}(\text{"twop34-44.txt"}) := out$

$$\frac{Eu_N}{Cs_N} = 4.556 \cdot 10^{-5}$$

filein := "two44-52.txt"

Well 21-02-09

$A := READPRN(filein)$ $\quad yr := A^{\langle 1 \rangle}$ $\quad net := A^{\langle 7 \rangle}$ $\quad bkg := A^{\langle 6 \rangle}$ $\quad max := A^{\langle 4 \rangle}$

$N := last(yr)$ $\quad N = 589$ $\quad i := 0..N$ $\quad k := 0..300$ $\quad j := 0..299$ $\quad \tau eu := 1$

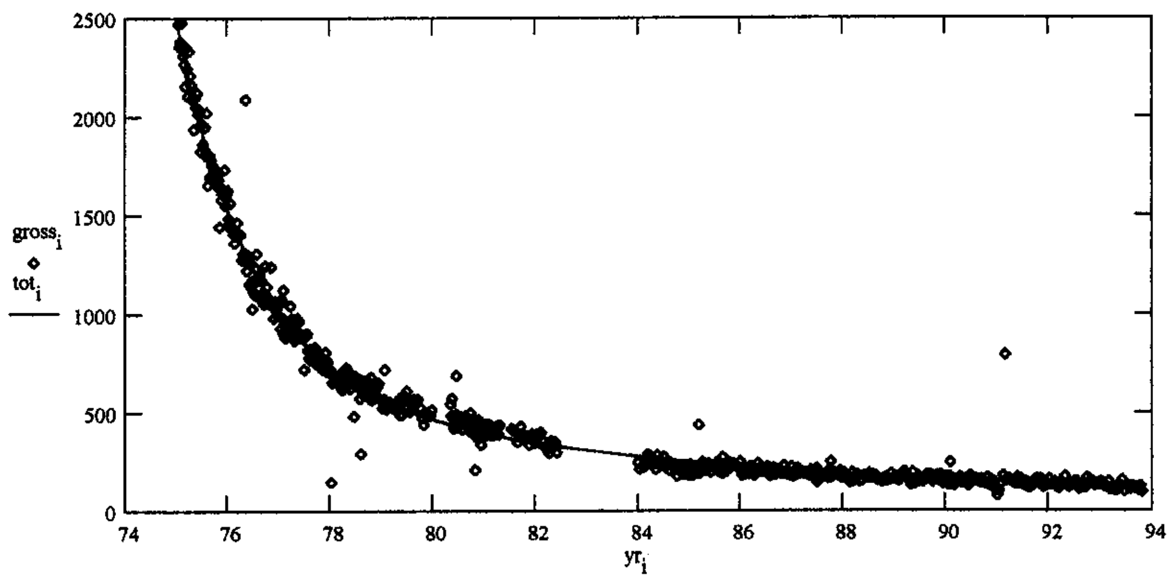
$\tau co := 5.27$ $\quad \tau cs := 30.17$ $\quad aco := 613$ $\quad acs := 106$

Eu variables are Ru-106 $\quad aeu := 1780$

$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $\quad Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $\quad Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1$ $\quad tot_i := Cs_i + Eu_i + C$

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1, a3, a2) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + \left[a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} + a2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \right]\right]\right]^2$$

Given

$ssq(acs, aeu, aco) = 0$ $\quad 1 = 1$ $\quad 2 = 2$

$$\begin{bmatrix} \alpha cs \\ \alpha eu \\ \alpha co \end{bmatrix} := Minerr(acs, aeu, aco)$$

$\alpha cs = 106$ Cs-137 $\quad \alpha eu = 1.78 \cdot 10^3$ Ru-106 $\quad \alpha co = 613$ Co-60

$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $\quad Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $\quad Co_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $\quad \frac{\alpha cs}{\alpha eu} = 0.06$

$tot_i := Cs_i + Eu_i + Co_i$

$out^{\langle 0 \rangle} := yr$ $\quad out^{\langle 1 \rangle} := tot$ $\quad WRITEPRN("twop44-52.txt") := out$ $\quad \frac{Eu_N}{Cs_N} = 5.576 \cdot 10^{-5}$

Borehole 22-03-01

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity

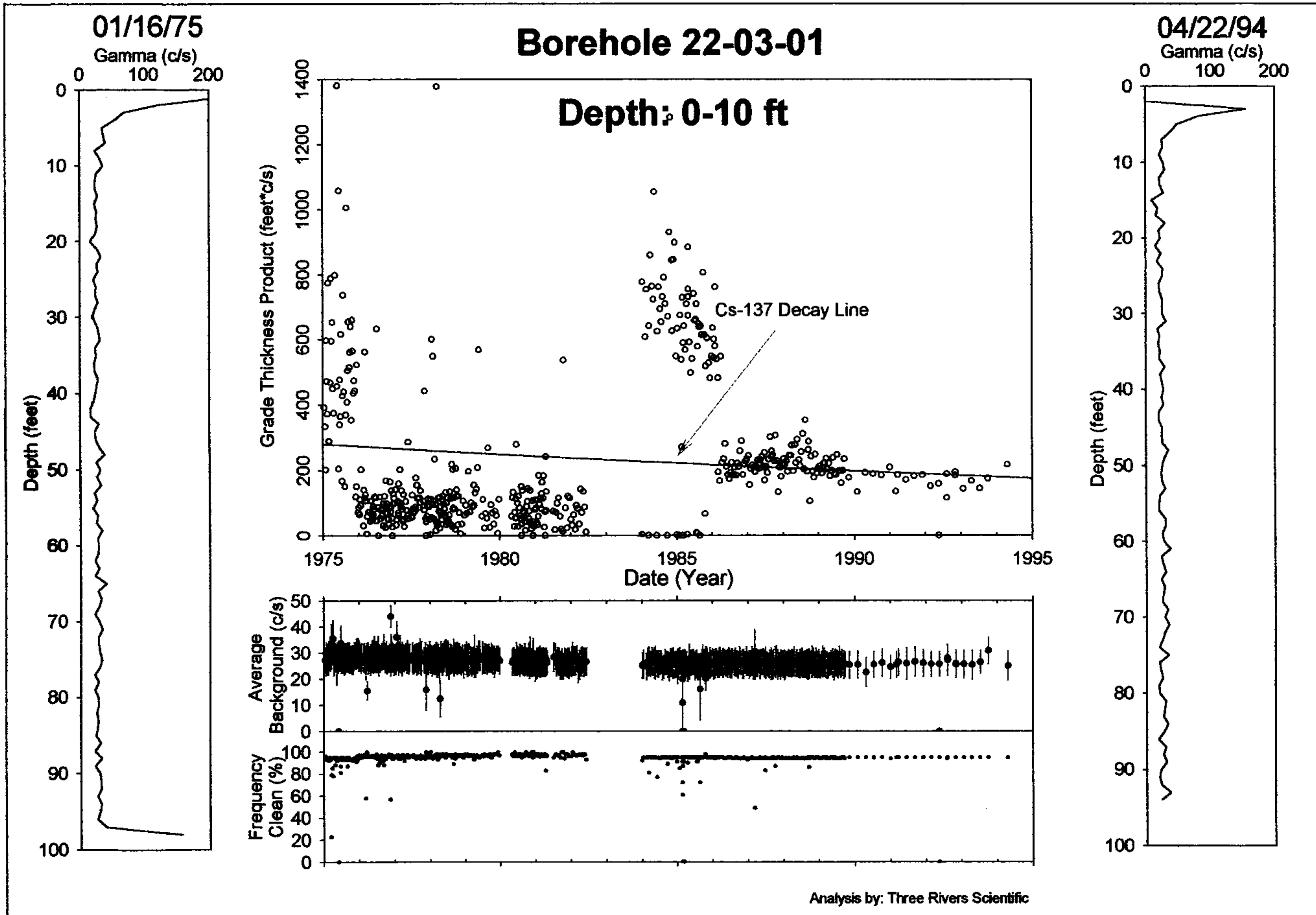
Grade thickness product from 0 to 10 feet is erratic indicative of tank farm activities such as transfer line operations.

Gross Gamma Survey Information

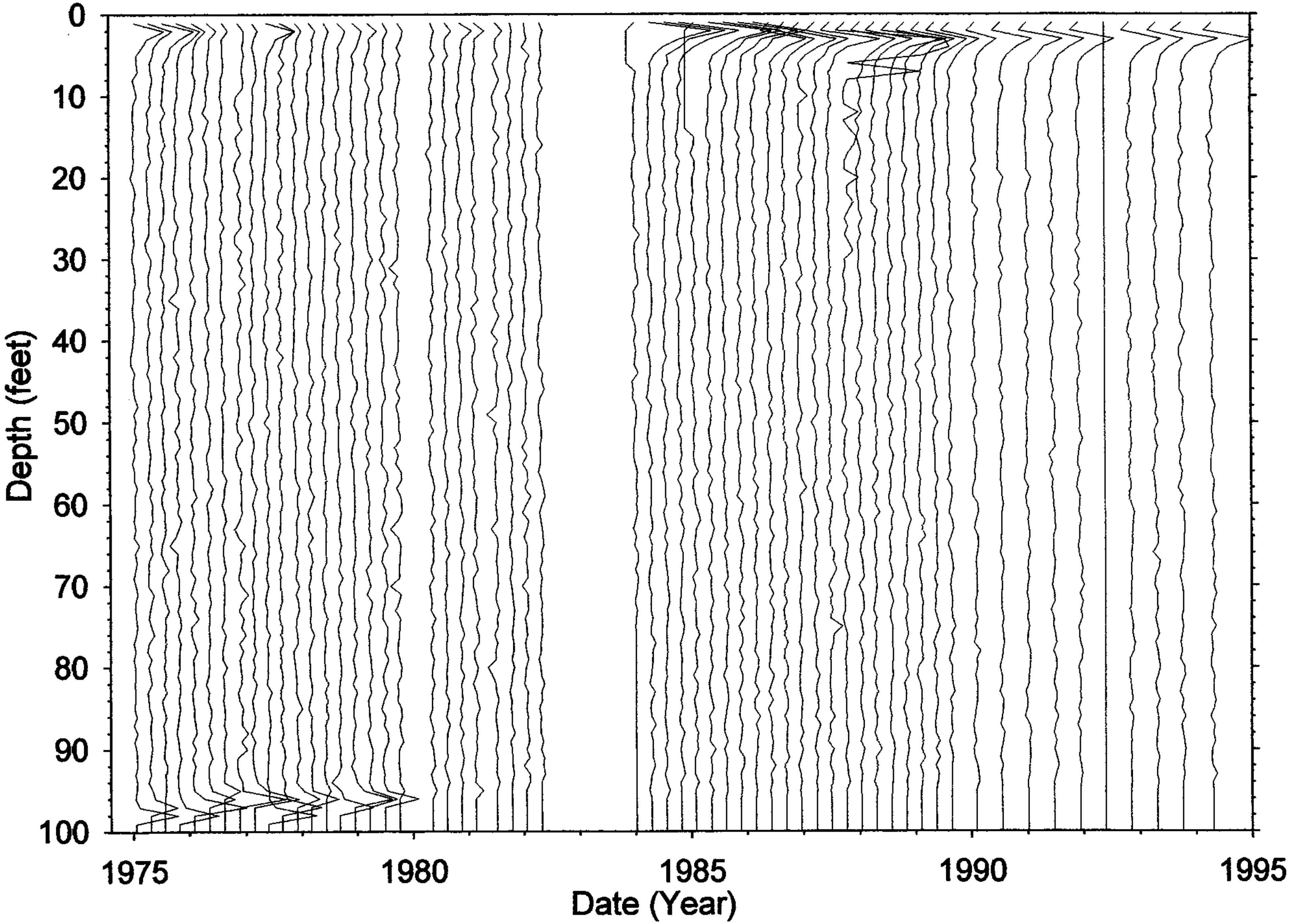
Probe Type :	04: NaI
Other Probe Types :	02: Red GM, 03: Neutron
Borehole Depth :	95 ft
Survey Depth :	95 ft
First Survey Date :	1/16/1975
Last Survey Date :	4/22/1994
Number Surveys :	538

Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 Tank Farm Activity	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	


Borehole 22-03-01
Depth: 0-10 ft
01/16/75
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
04/22/94
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific

Borehole 22-03-01



00 144

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Borehole 22-03-04

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity
Contamination (Cs-137) from 10-30 feet is Tank Farm Activity
Contamination (Sb-125) from 40-55 feet is Stable
Contamination (Co-60 & Sb-125) from 55-85 feet is Stable

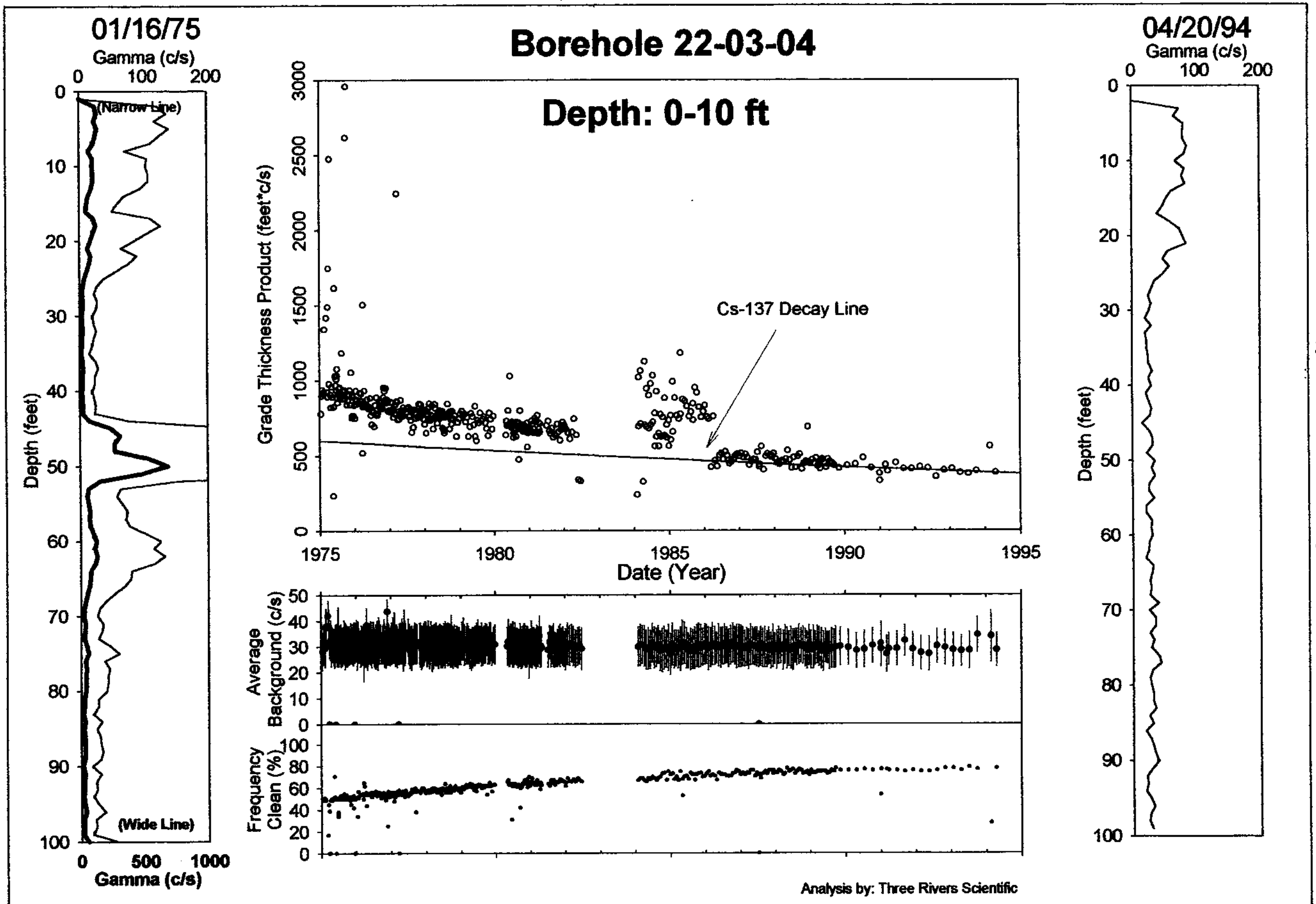
Grade thickness products from 0 to 10 and 10 to 30 feet are erratic, indicative of tank farm activities such as transfer line operations.
Grade thickness product from 40 to 55 feet is decreasing consistent with Sb-125 (HPGe identified) from 1975 to 1994. Note that Co-60 is HPGe identified, but at low levels for this interval.
Grade thickness product from 55 to 85 feet is decreasing consistent with a least squares fit for Co-60 (HPGe identified) and Sb-125 (hypothesis) from 1975 to 1994. The least squares fit results in gross gamma contribution ratio of Co-60 to Sb-125 of 0.36 as of Jan 1975. Special note, the HPGe did identify Sb-125 at shallower depths than 55-85, but the Sb-125 in 55-85 feet decayed to a level below detection.

Gross Gamma Survey Information

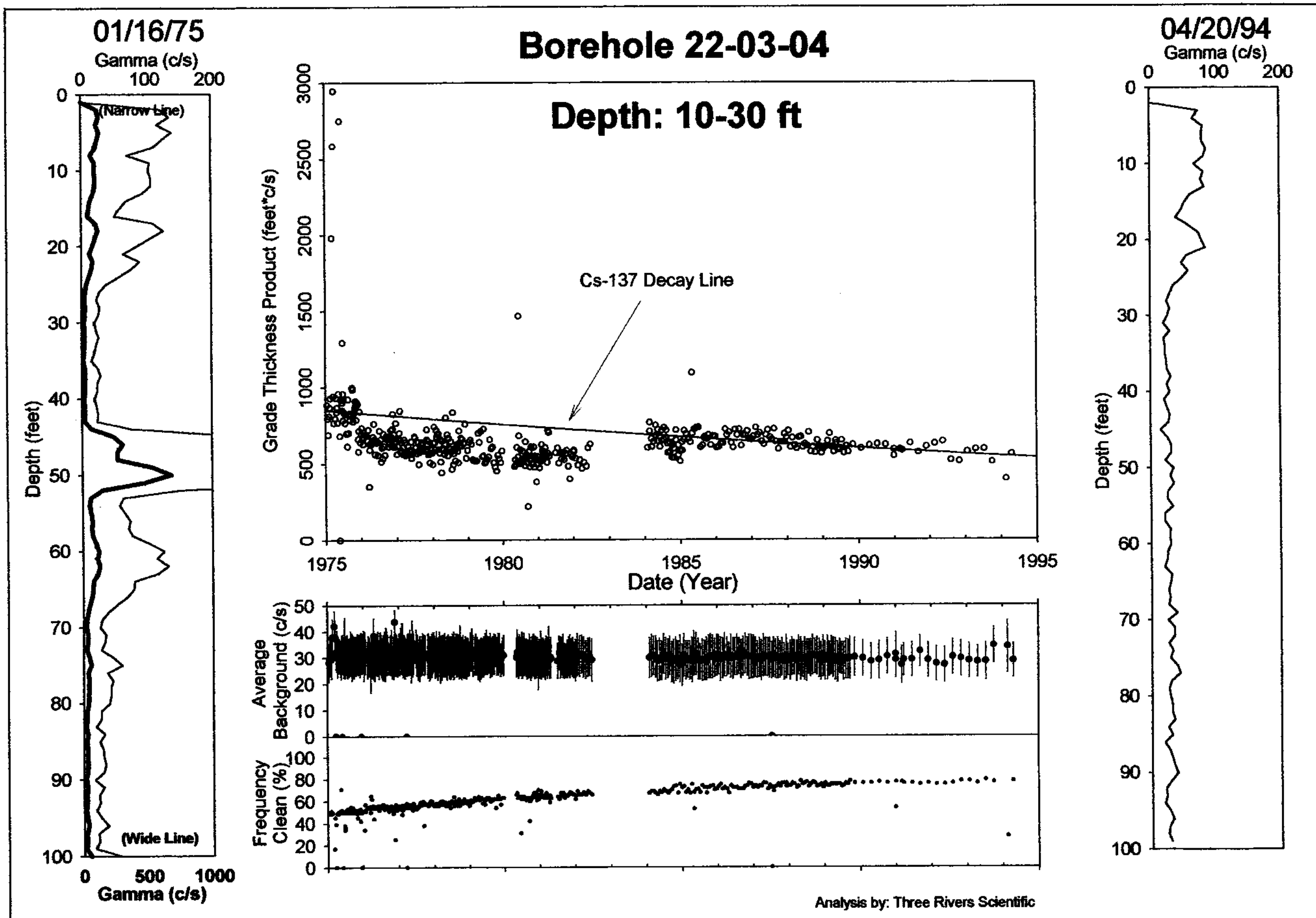
Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/16/1975
Last Survey Date :	4/20/1994
Number Surveys :	457

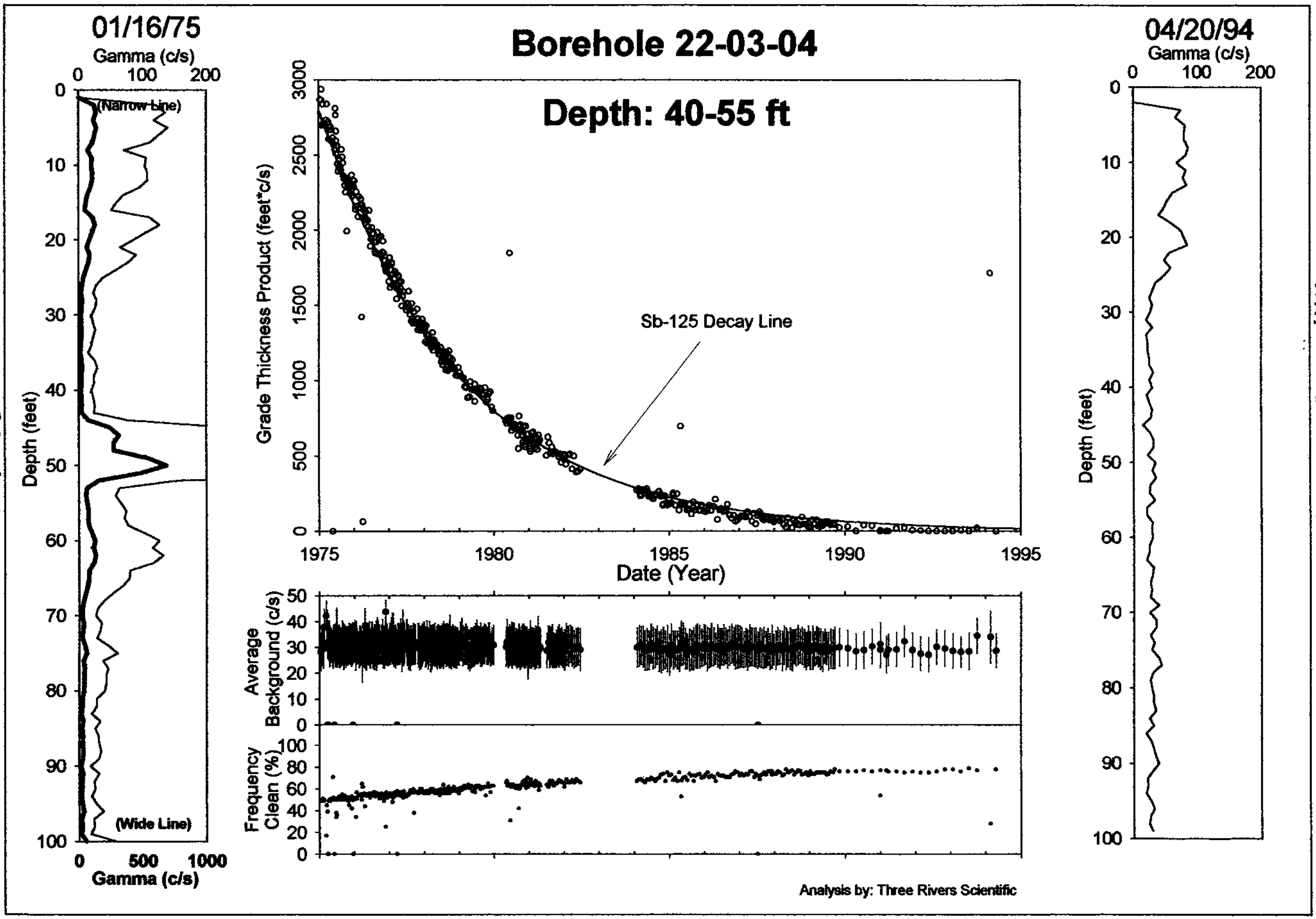
Analysis Notes

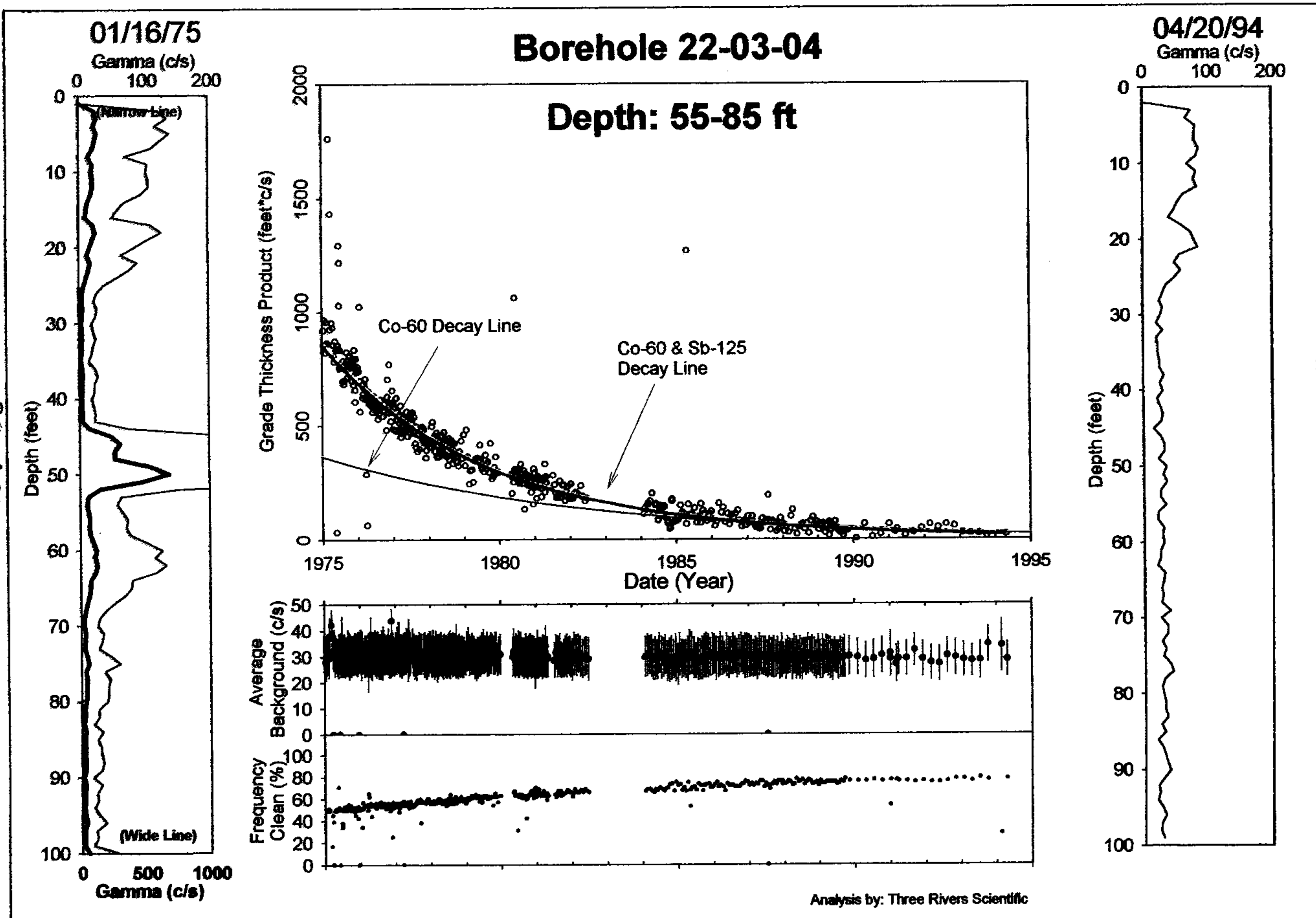
Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 & 10-30 Tank Farm Activity 40-55 & 55-85 Stable	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	



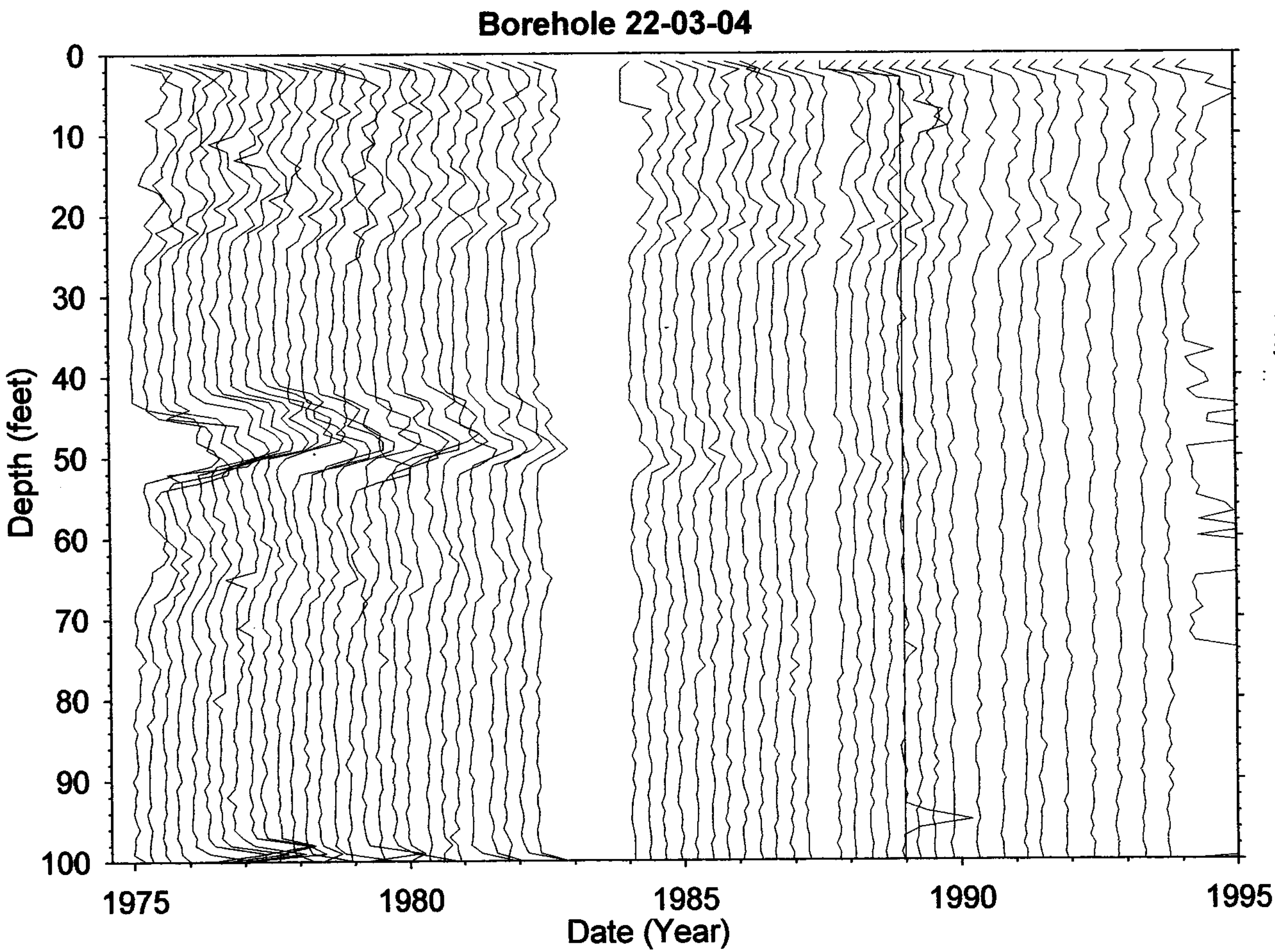
Borehole 22-03-04
Depth: 0-10 ft
01/16/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
04/20/94
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific


Borehole 22-03-04
Depth: 10-30 ft
01/16/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
04/20/94
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific


01/16/75
Gamma (c/s)
0
100
200
(Narrow Line)
Depth (feet)
(Wide Line)
500
1000
Gamma (c/s)
Borehole 22-03-04
Depth: 40-55 ft
Grade Thickness Product (feet*c/s)
Sb-125 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
04/20/94
Gamma (c/s)
Depth (feet)



Borehole 22-03-04
Depth: 55-85 ft
01/16/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Co-60 & Sb-125
Decay Line
Date (Year)
Average
Background (c/s)
Frequency
Clean (%)
Analysis by: Three Rivers Scientific
04/20/94
Gamma (c/s)
Depth (feet)



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00 150

Borehole 22-03-05

Contamination (Cs-137) from 0-5 feet is Undetermined
Contamination (Cs-137) from 5-15 feet appears Stable
Contamination (Cs-137) from 15-60 feet appears Stable
Contamination (Cs-137) from 60-85 feet appears Stable

Grade thickness product from 0 to 5 feet is undetermined due to lack of depth control near the surface and the short time span of the data.

Grade thickness product from 5 to 15 feet is decreasing consistent with Cs-137 (HPGe identified) from 1980 to 1990.

Grade thickness product from 15 to 60 feet is decreasing consistent with Cs-137 (HPGe saturated, but observed above and below) as determined by the red GM, since the green GM count rate limits were exceeded.

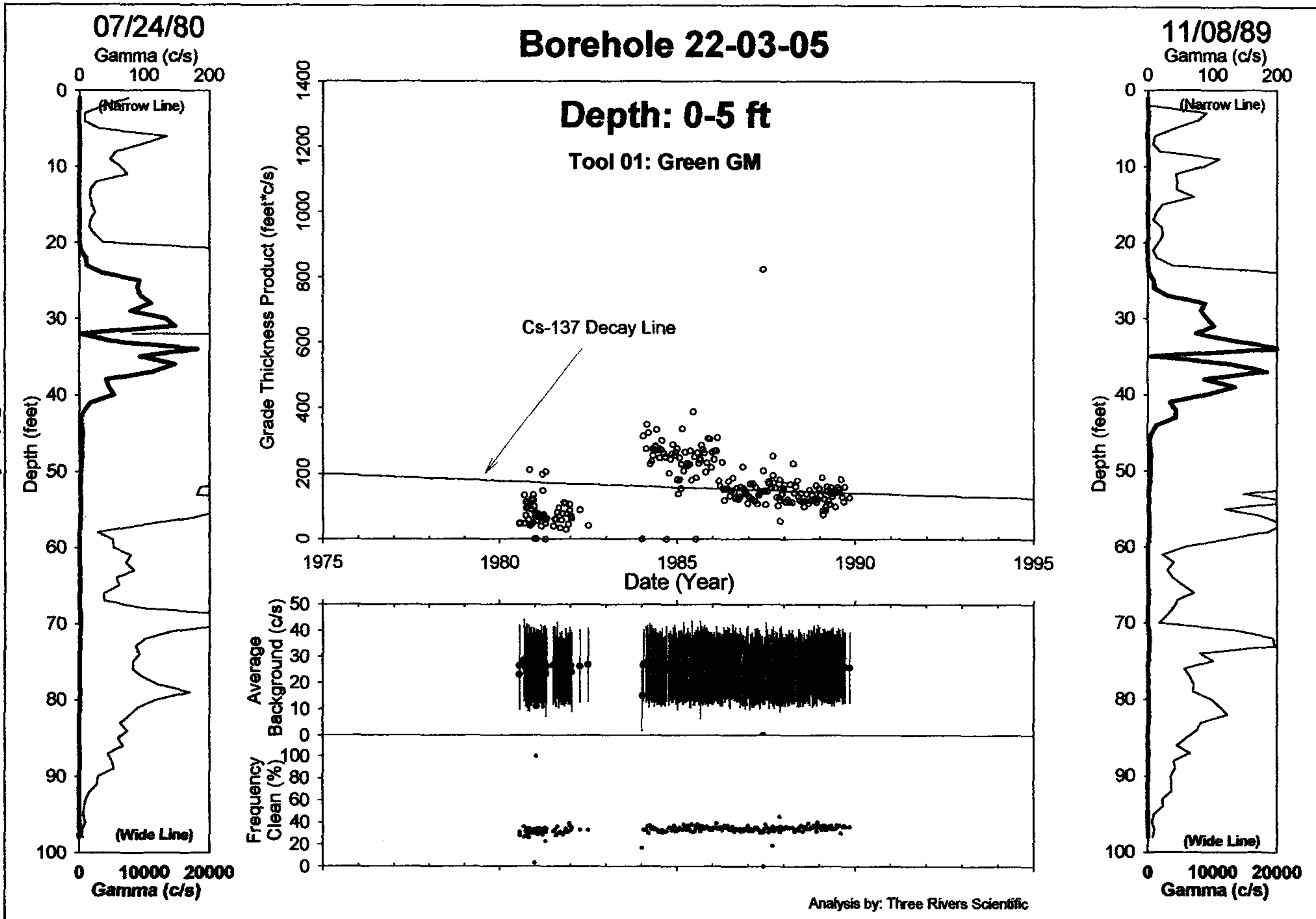
Grade thickness product from 60 to 85 feet is decreasing consistent with Cs-137 (HPGe identified). The very slight deviation from Cs-137 early cannot be claimed as deviation given the short duration of the data collection. Special note, the HPGe did identify Co-60 in this interval, but the levels are low and dominated by the very high Cs-137 concentration.

Gross Gamma Survey Information

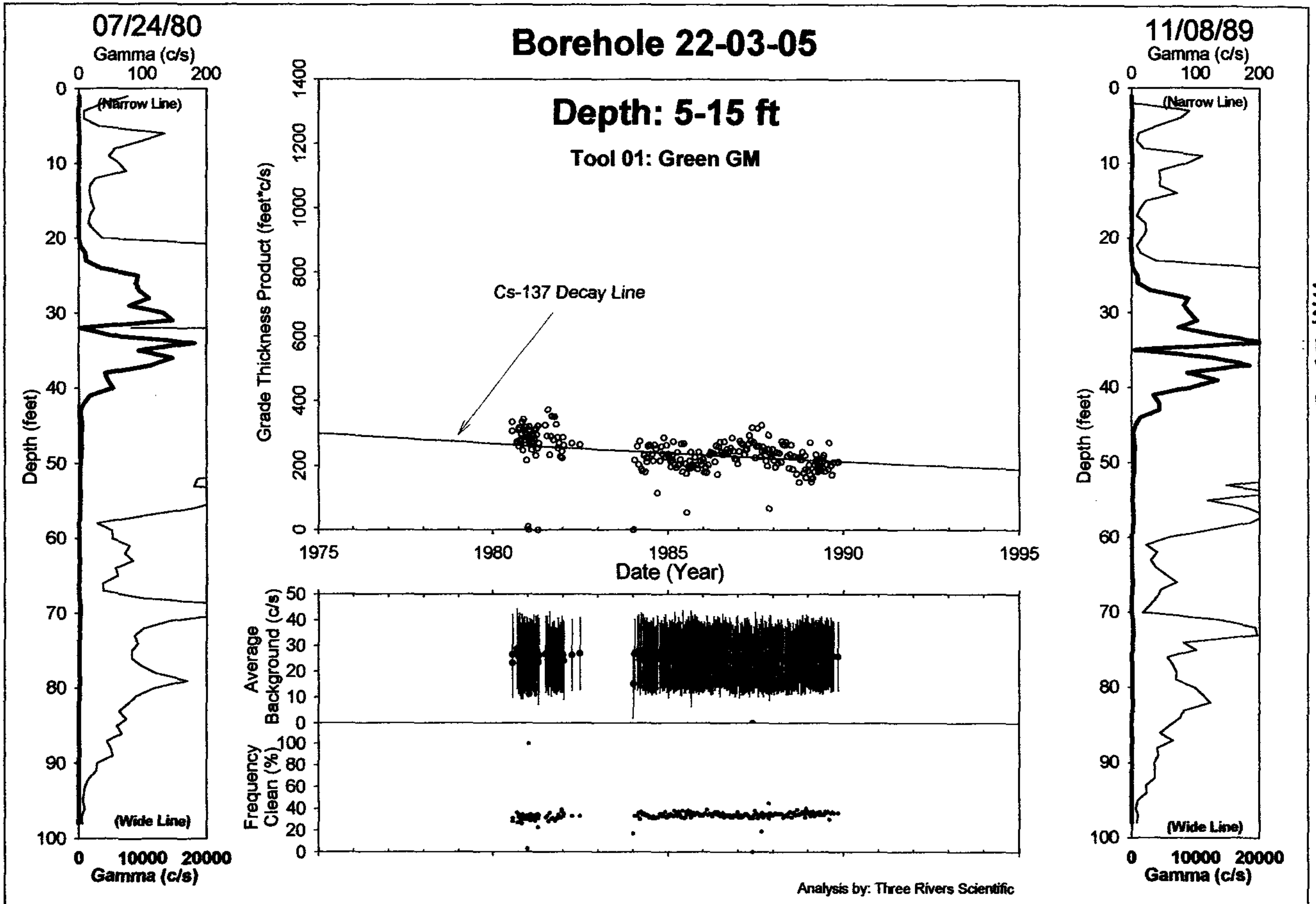
Probe Type :	01: Green GM, & 02: Red GM
Other Probe Types :	14: Shielded NaI, 03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	7/24/1980 tool 01 & 5/5/80 tool 02
Last Survey Date :	11/8/1989 tool 01 & 11/8/89 tool 02
Number Surveys :	235 tool 01 & 255 tool 02

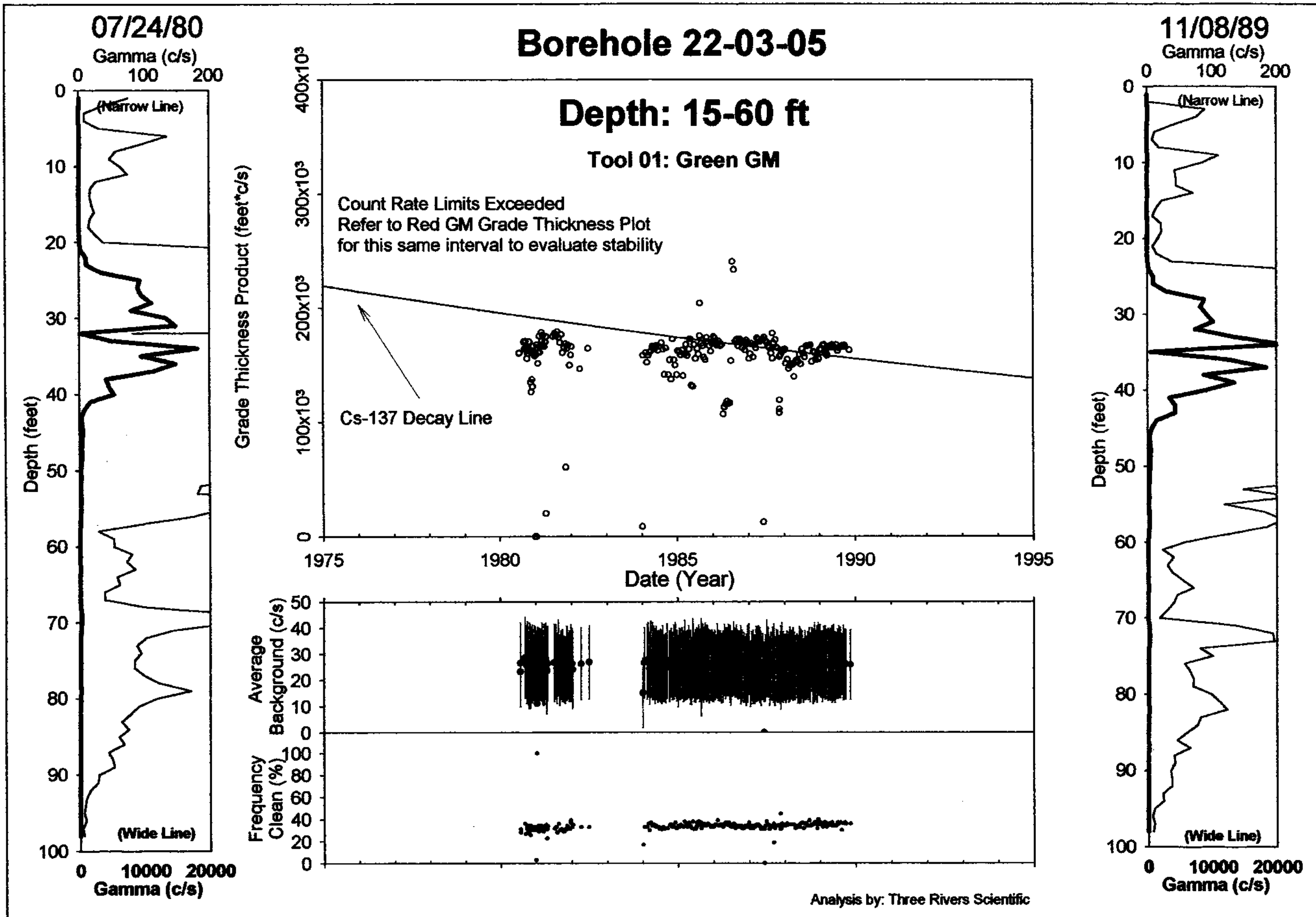
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	Threshold 0<val<50 tool 02 Threshold 0<val<20 tool 01
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-5 Undetermined 5-15, 15-60, & 60-85 Stable
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific


Borehole 22-03-05
Depth: 0-5 ft
Tool 01: Green GM
07/24/80
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
11/08/89
Analysis by: Three Rivers Scientific

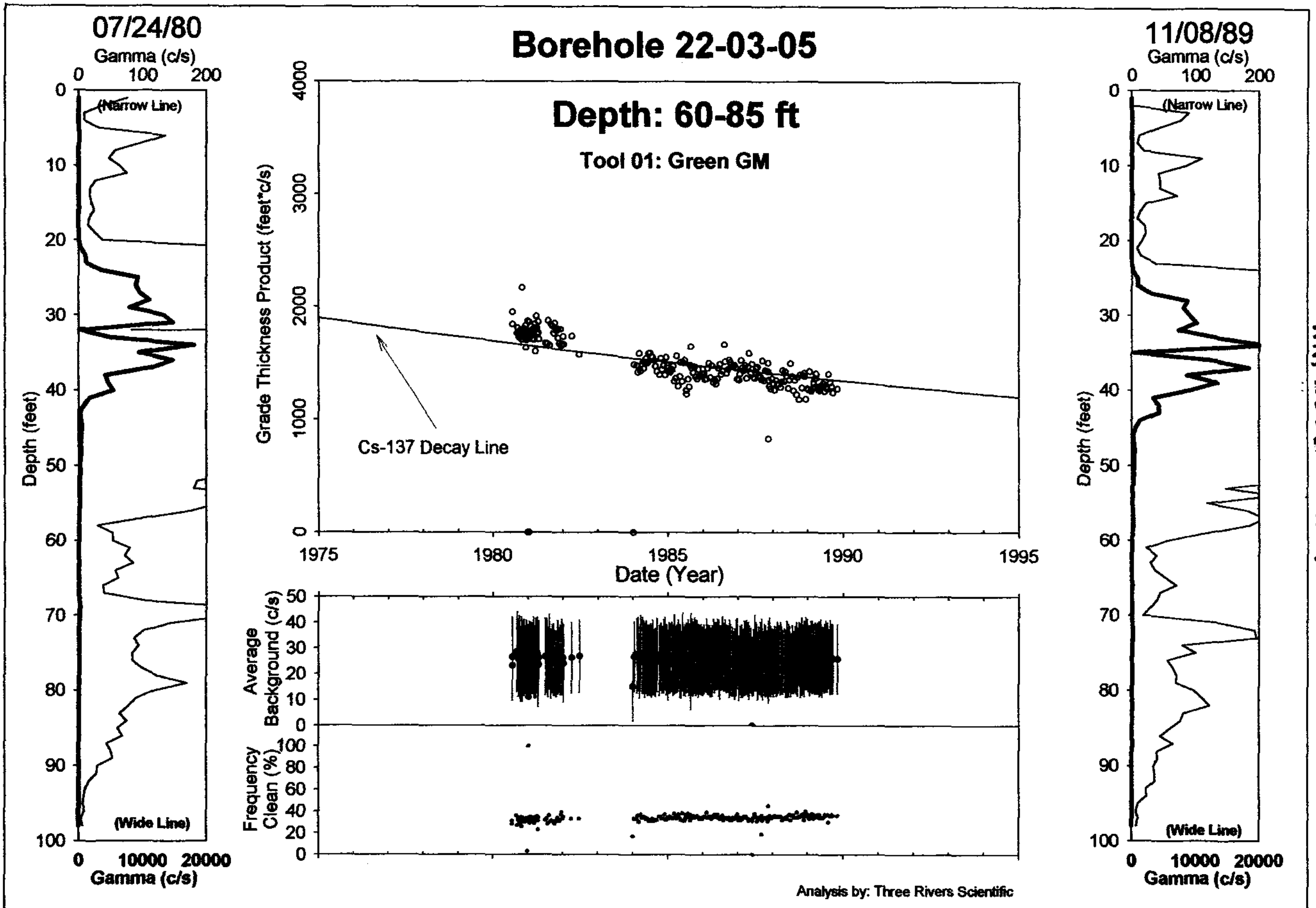
00 152


Borehole 22-03-05
Depth: 5-15 ft
Tool 01: Green GM
07/24/80
11/08/89
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific



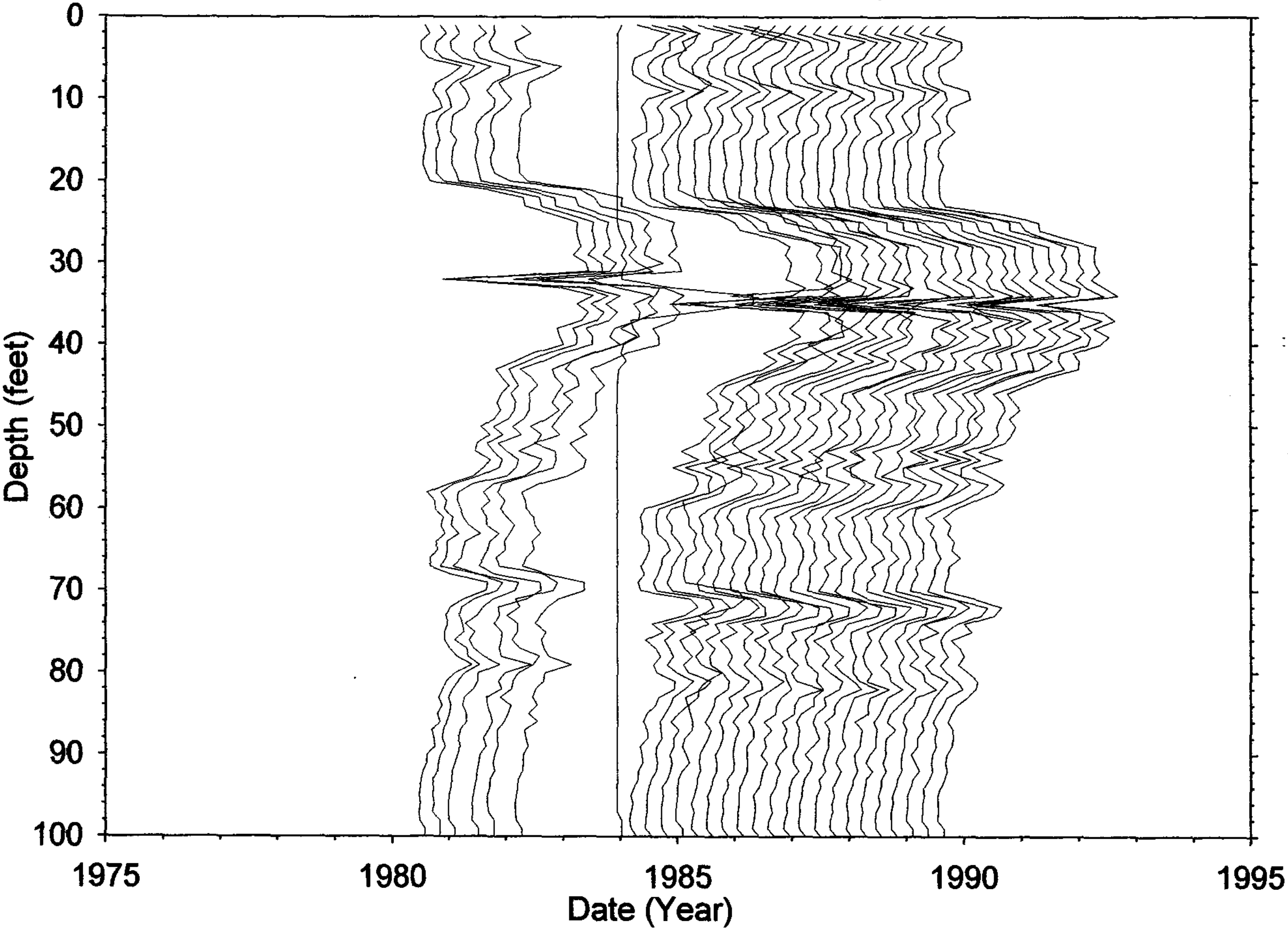
00 154

HNF-3532 -REV0

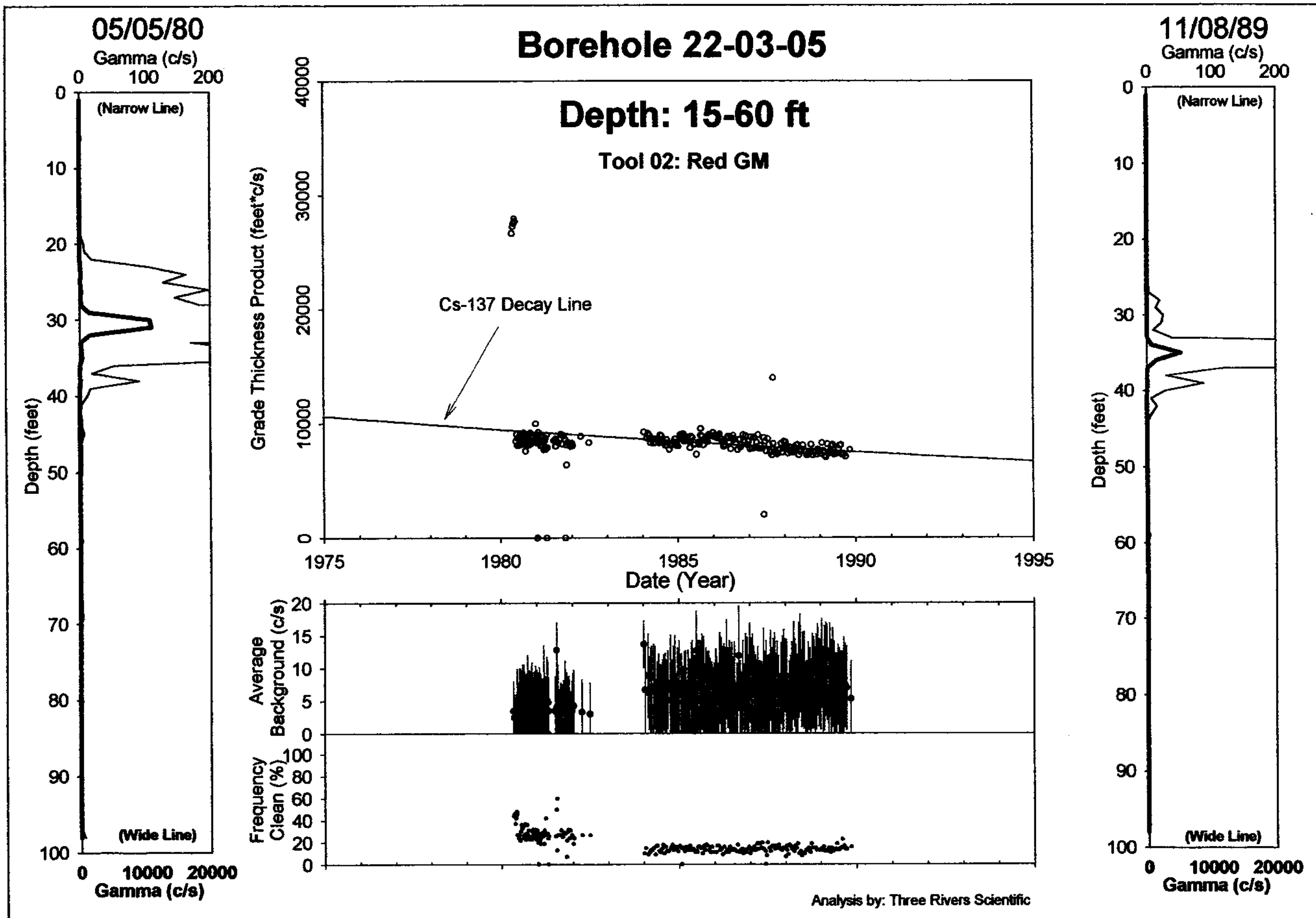


Borehole 22-03-05
Depth: 60-85 ft
Tool 01: Green GM
07/24/80
11/08/89
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

Borehole 22-03-05 Tool 01: Green GM

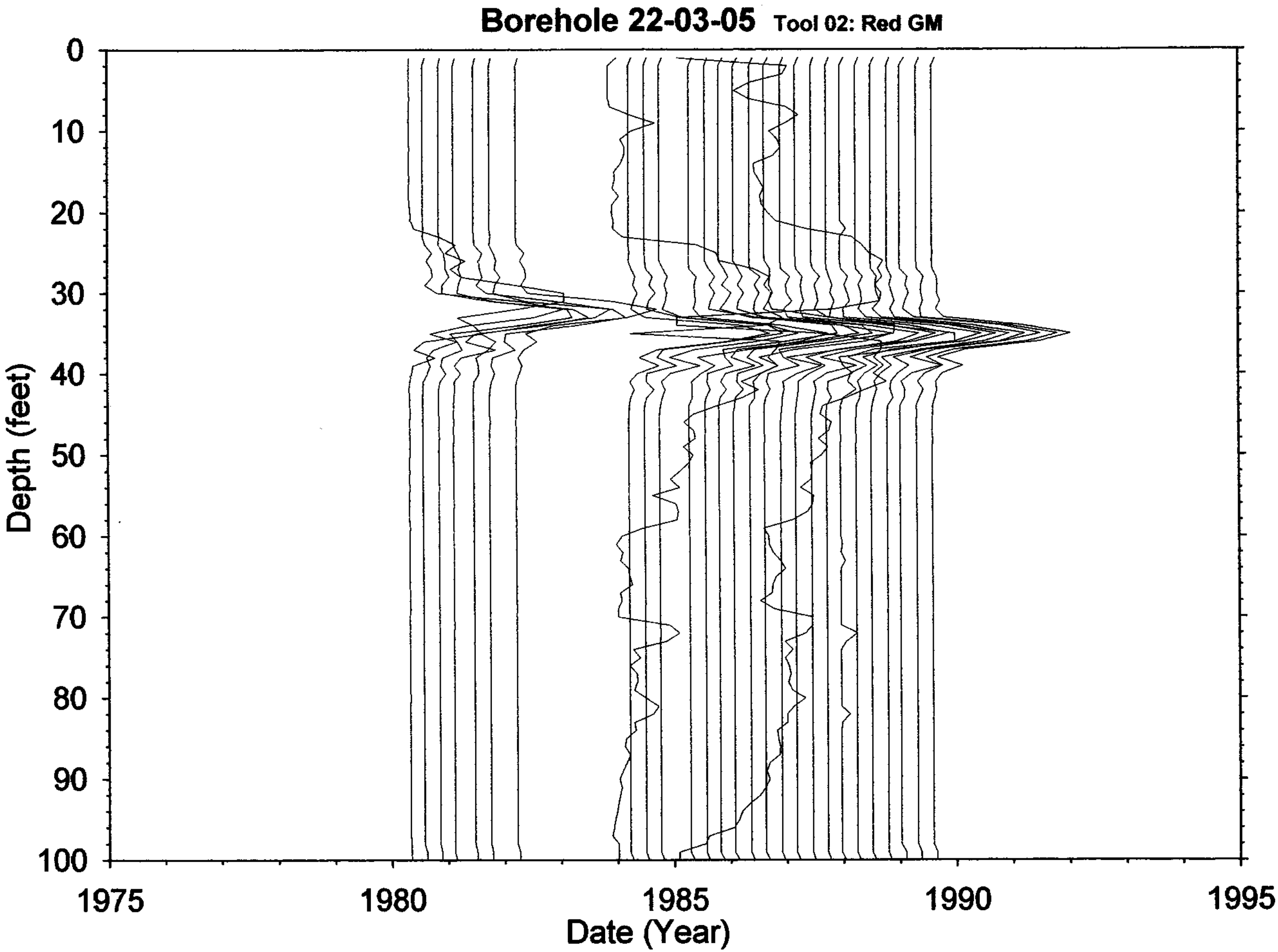


HNF-3532-REV0



05/05/80
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
(Wide Line)
0 10000 20000
Gamma (c/s)
Borehole 22-03-05
Depth: 15-60 ft
Tool 02: Red GM
Grade Thickness Product (feet*c/s)
0 10000 20000 30000 40000
Cs-137 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 5 10 15 20
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
11/08/89
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
(Wide Line)
0 10000 20000
Gamma (c/s)

00 157



00 158

HNF-3532 -REV0

Borehole 22-03-06

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity
Contamination (Cs-137) from 20-28 feet appears Stable
Contamination (Cs-137, Co-60, & Sb-125) from 37-48 feet is Stable
Contamination (Ru-106, & Sb-125) from 48-60 feet is Stable
Contamination (Co-60, Ru-106, & Sb-125) from 60-94 feet is Stable
Contamination (Sb-125) from 94-105 feet is Stable (when logged)

Grade thickness product Cs-137 (HPGe identified) from 0 to 10 feet is erratic indicative of tank farm activities such as transfer line operations.

Grade thickness product from 20 to 28 feet is decreasing consistent with Cs-137 (HPGe identified) from 1975 to 1993. Note that background subtraction may account for the small deviations observed.

Grade thickness product from 37 to 48 feet is decreasing consistent with a least squares fit for Cs-137 (HPGe identified), Co-60 (HPGe identified), and Sb-125 (HPGe identified) from 1975 to 1993. The least squares fit results in gross gamma contribution ratios of Cs-137:Sb-125:Co-60 of 690:80:1265 as of Jan 1975. The stack plots shows this interval to change profile over 1975 to 1993, which indicates the slower decay components are located in the upper section.

Grade thickness product from 48 to 60 feet is decreasing consistent with a least squares fit for Ru-106 (hypothesis), and Sb-125 (hypothesis) from 1975 to 1993. The least squares fit results in gross gamma contribution ratios of Ru-106 to Sb-125 of 0.25 as of Jan 1975. Note, Co-60 was marginally identified in this interval, but not visible in gross gamma due to large Sb-125 contribution. Sb-125 present; but not at detection levels when HPGe data collected.

Grade thickness product from 60 to 94 feet is decreasing consistent with a least squares fit for Ru-106 (hypothesis), Co-60 (HPGe identified), and Sb-125 (hypothesis) from 1975 to 1993. The least squares fit results in gross gamma contribution ratios of Ru-106:Sb-125:Co-60 of 581:3440:299 as of Jan 1975.

Grade thickness product from 94 to 105 feet is decreasing consistent with Sb-125 (hypothesis) from 1975 to mid 1983, when logging of this interval ceased.

Due to the complex nature of the intervals in this borehole, a depth shifting was required for all zones analyzed.

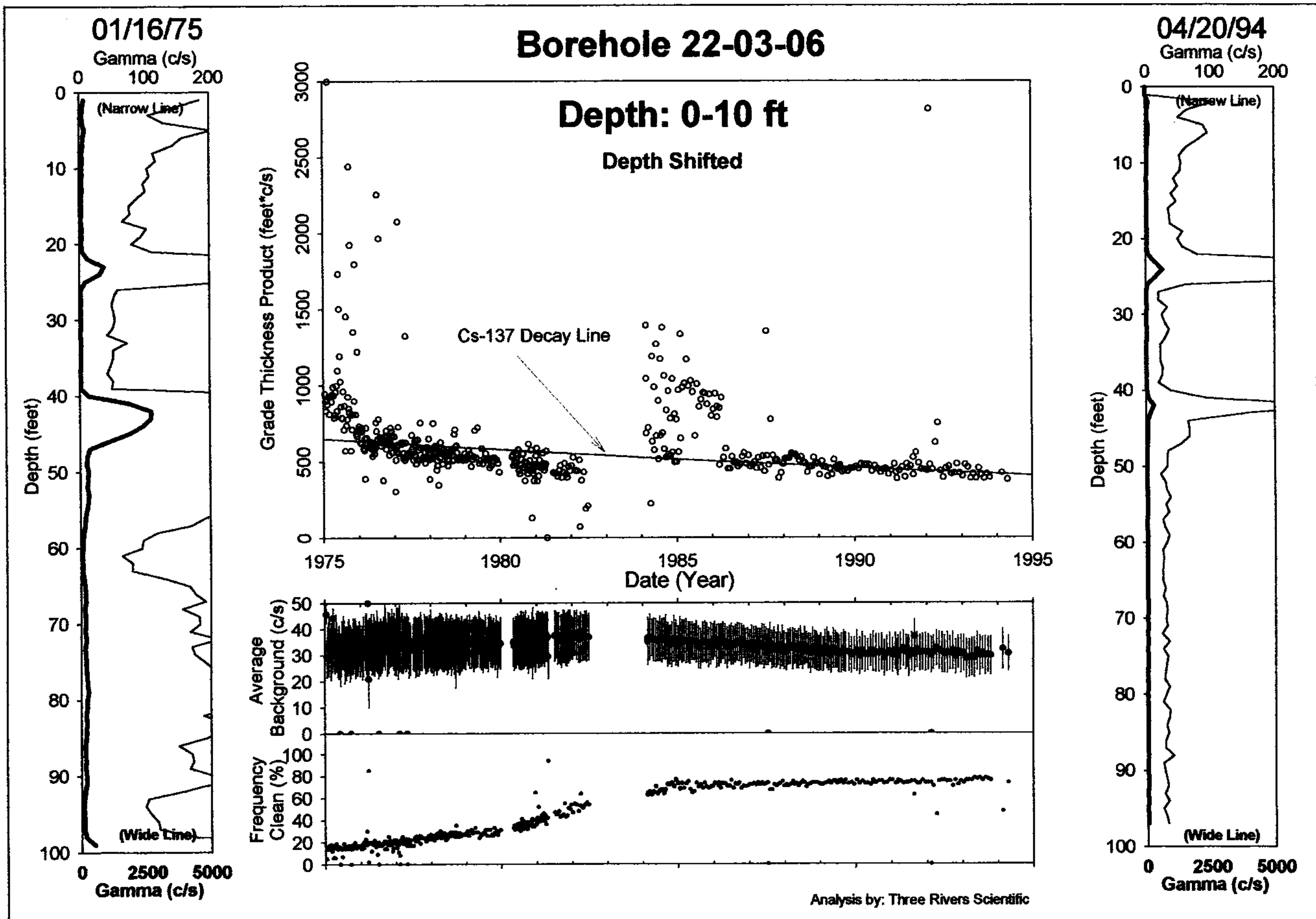
Borehole 22-03-06

Gross Gamma Survey Information

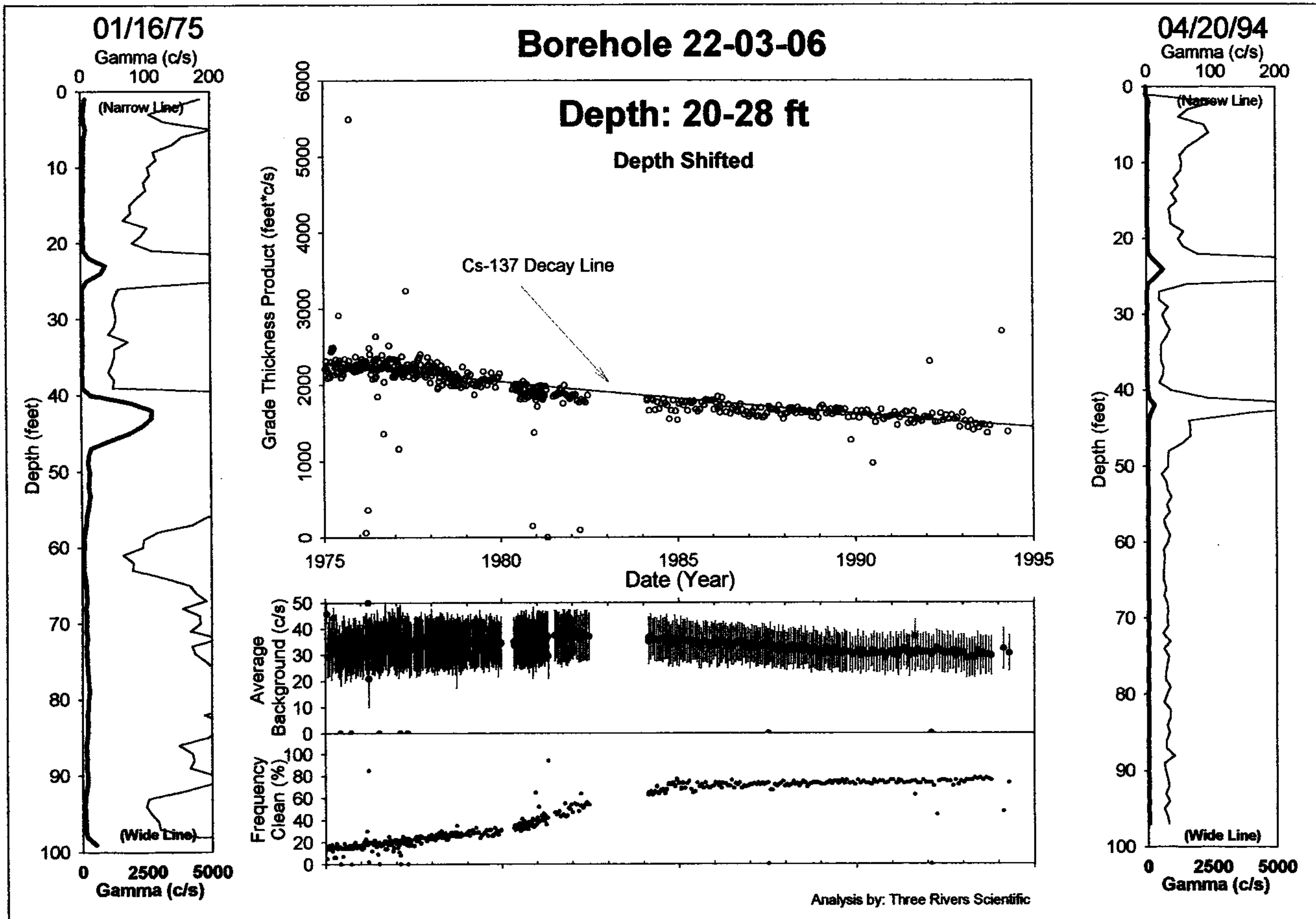
Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/16/1975
Last Survey Date :	4/20/1994
Number Surveys :	490

Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	Threshold 0<val<50 all zones but 60-94 least squares fit background
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 Tank Farm Activity 20-28, 37-48, 48-60, & 60-94 Stable 94-105 Stable (when logged)
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

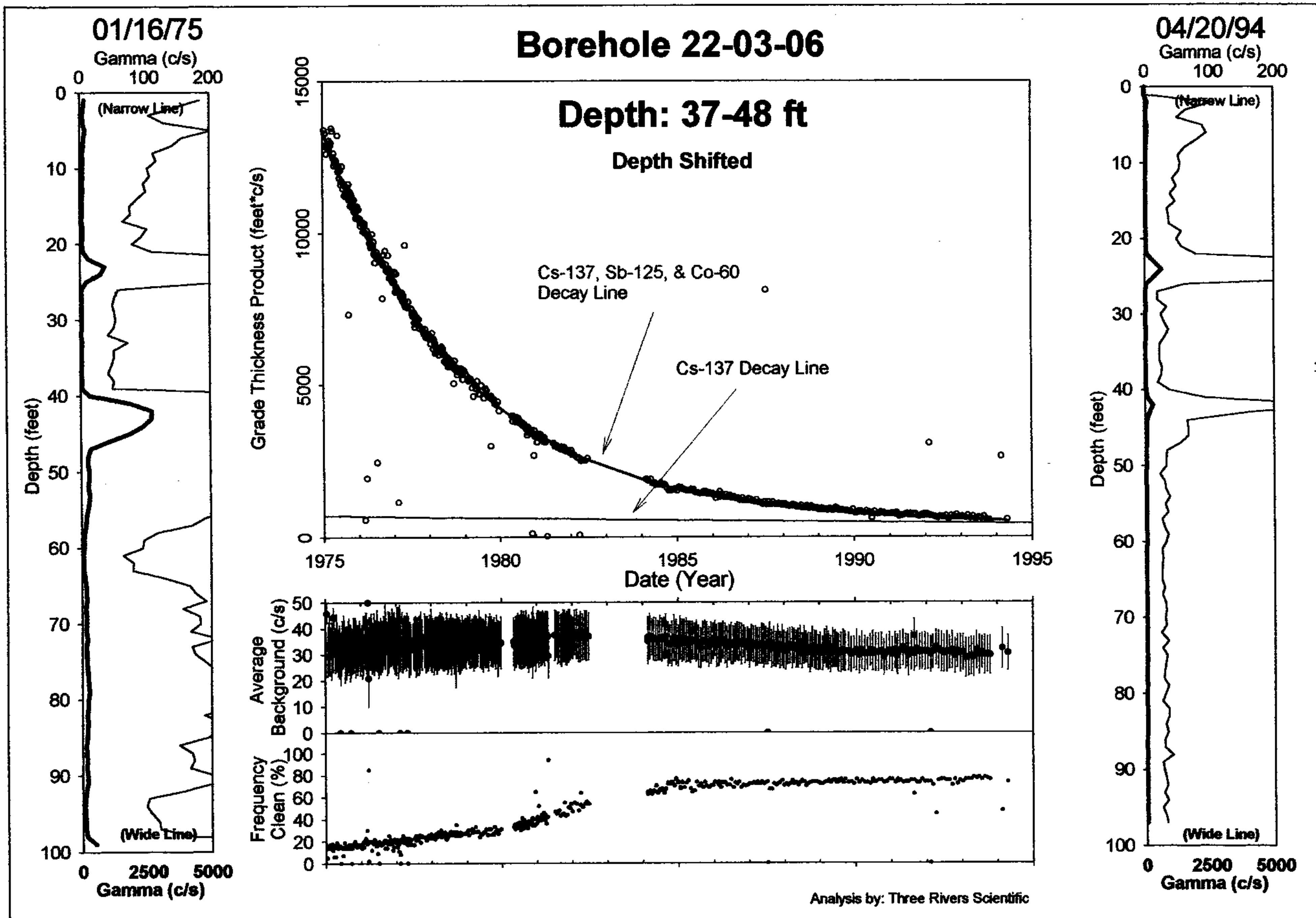


Borehole 22-03-06
Depth: 0-10 ft
Depth Shifted
01/16/75
04/20/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific



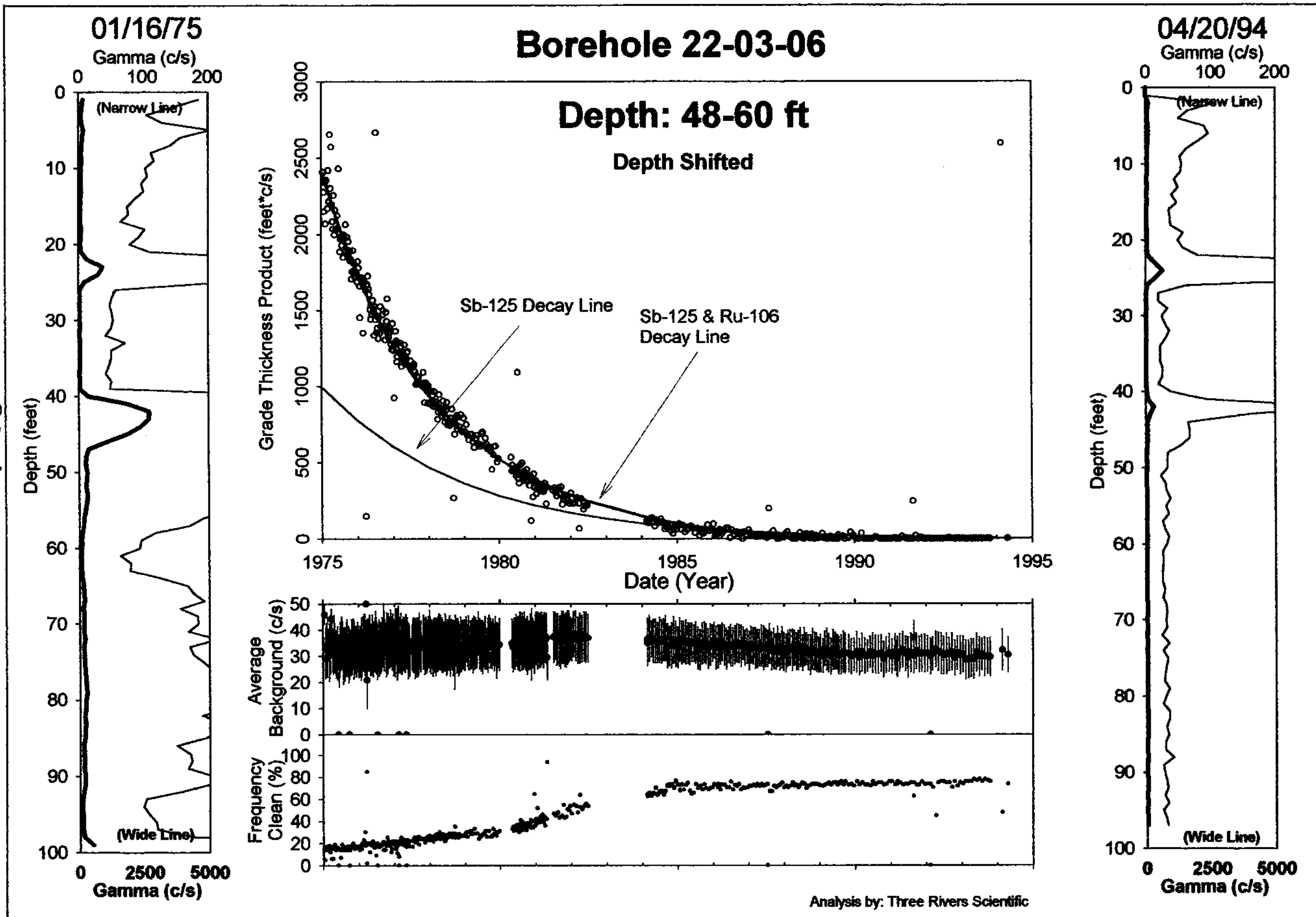
Borehole 22-03-06
Depth: 20-28 ft
Depth Shifted
Cs-137 Decay Line
Grade Thickness Product (feet*c/s)
Date (Year)
Average Background (c/s)
Frequency Clean (%)
01/16/75
04/20/94
Gamma (c/s)
Depth (feet)
(Narrow Line)
(Wide Line)
Analysis by: Three Rivers Scientific

00 162



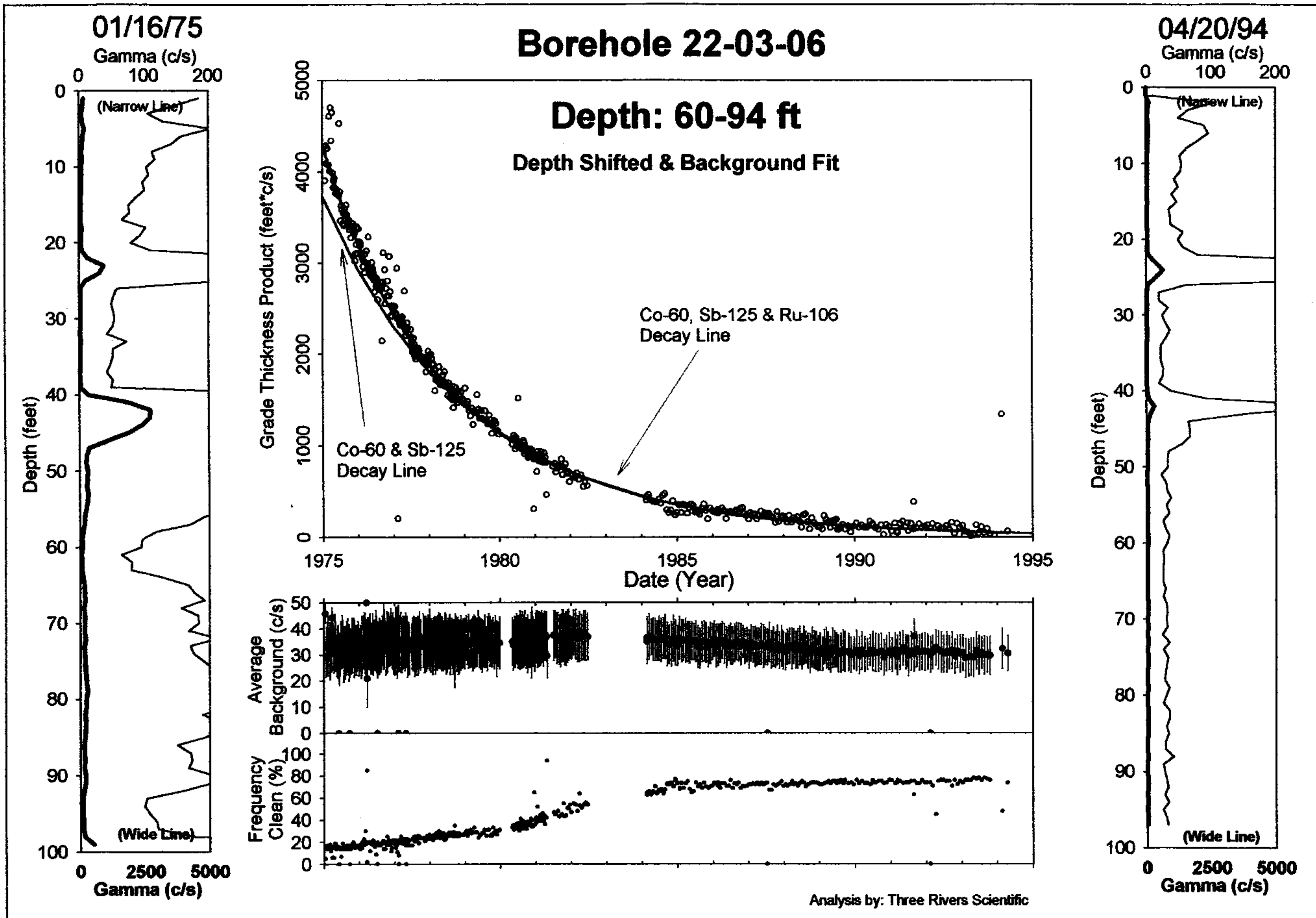
00 163

HNF-3532 -REV0

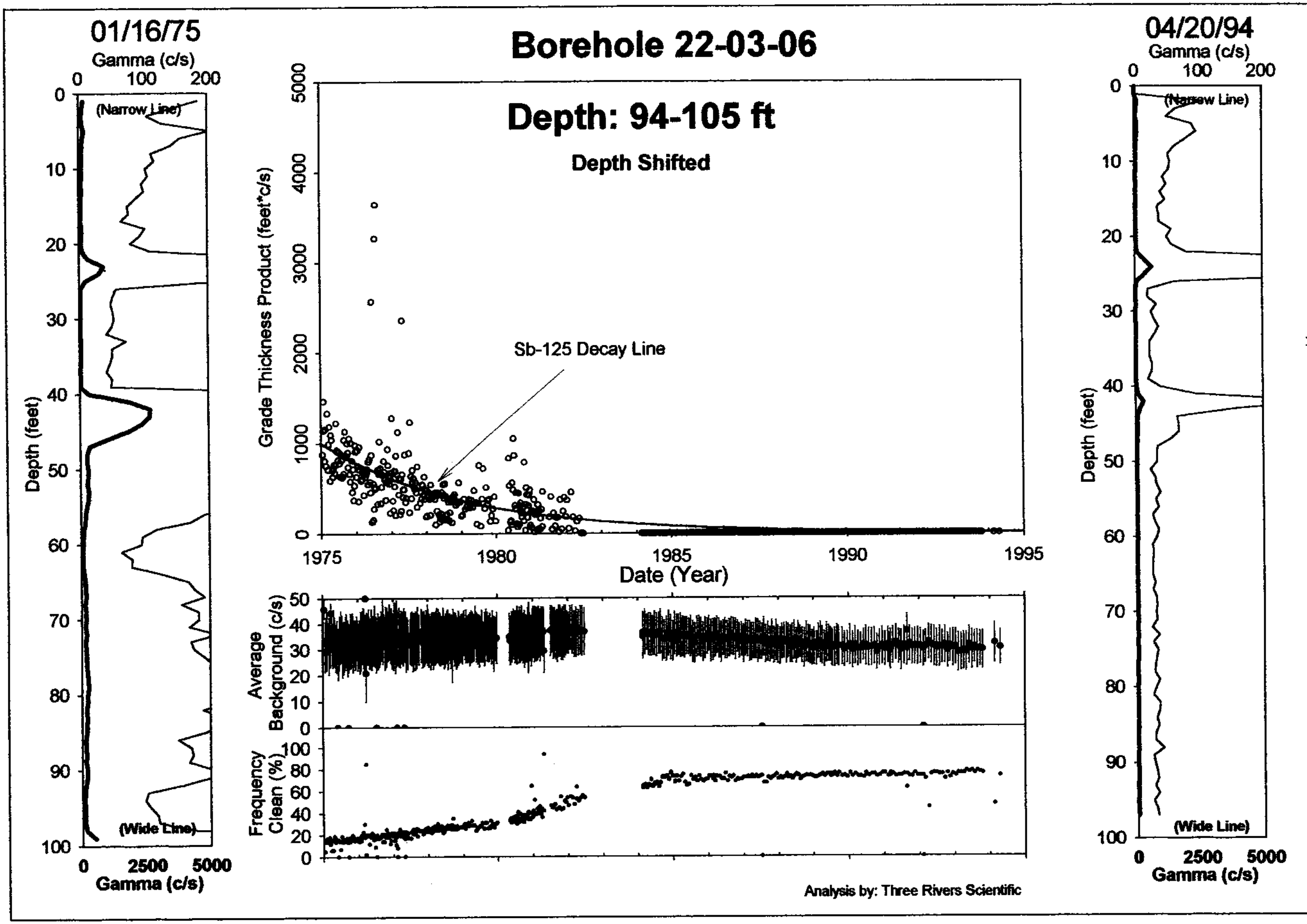


Borehole 22-03-06
Depth: 48-60 ft
Depth Shifted
01/16/75
04/20/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Sb-125 Decay Line
Sb-125 & Ru-106 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

00 165



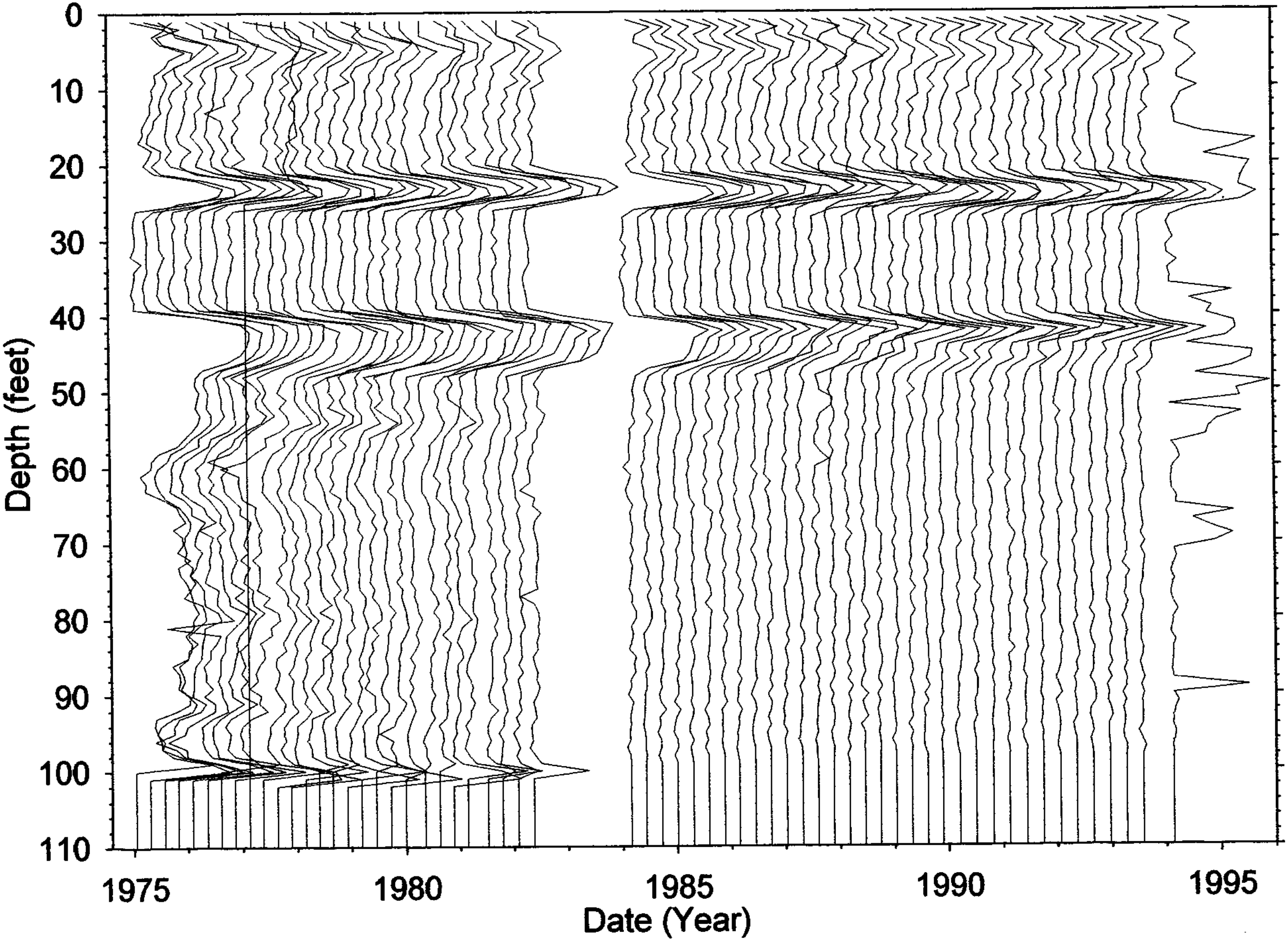
HNF-3532 -REV0



Borehole 22-03-06
Depth: 94-105 ft
Depth Shifted
01/16/75
04/20/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Sb-125 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

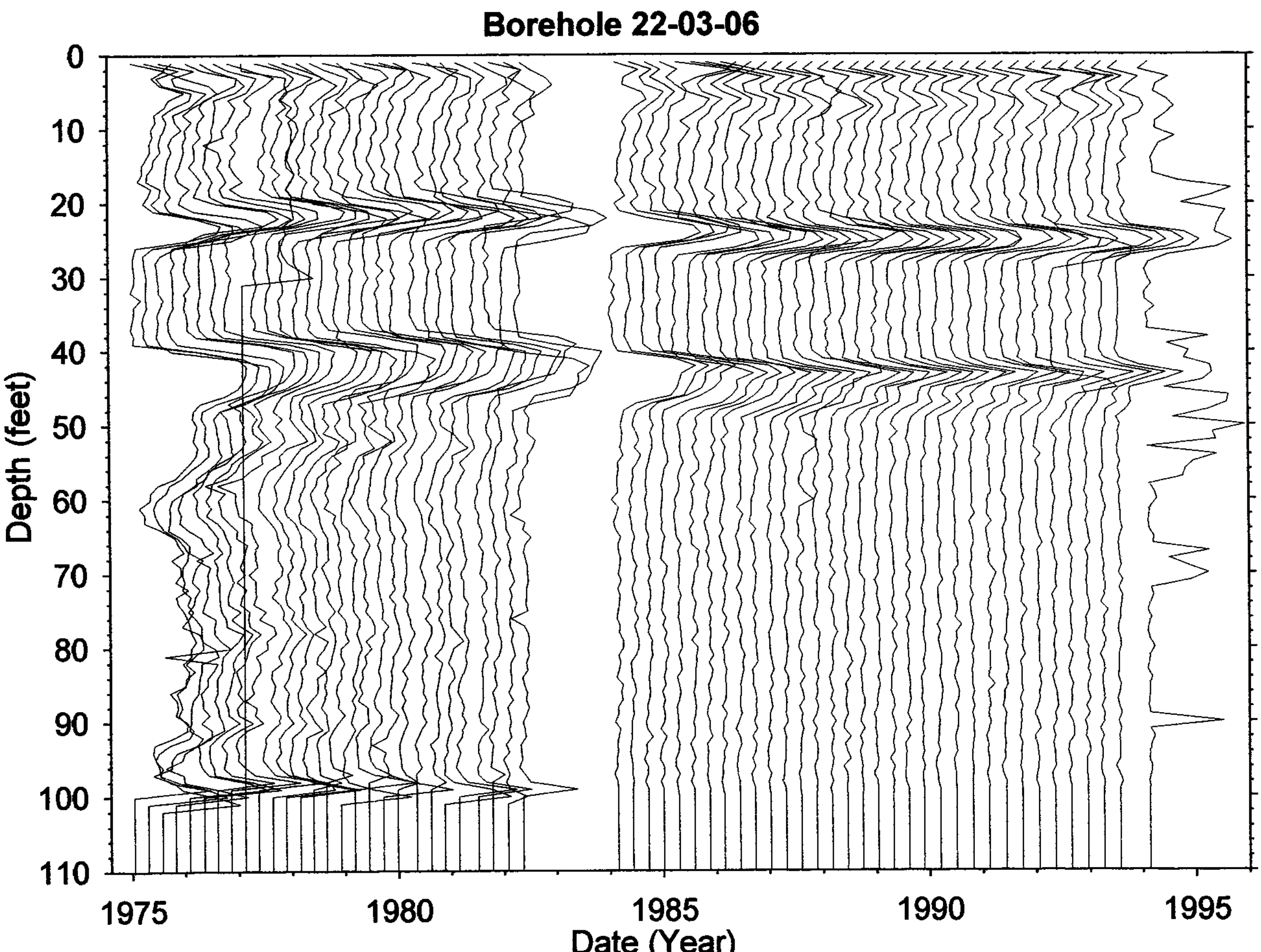
00 166

Borehole 22-03-06 Depth Shifted



HNF-3532 -REV0

00 167



98 168

HNF-3532 -REV0

Borehole 22-03-07

Contamination (Cs-137) from 0-8 feet is Tank Farm Activity
Contamination (Co-60 & Sb-125) from 47-62 feet is Stable
Contamination (Ru-106, & Co-60) from 62-90 feet is Stable

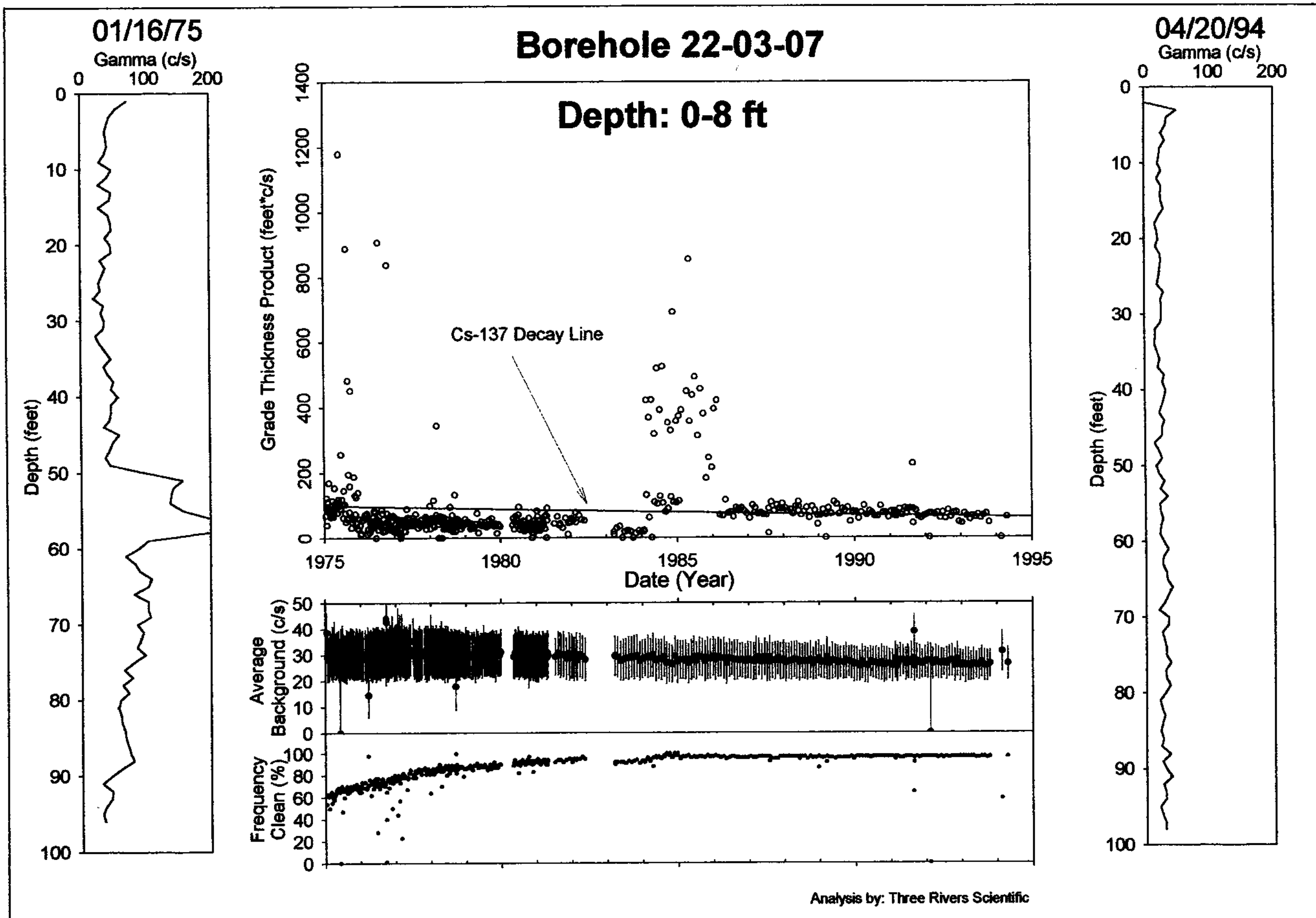
Grade thickness product Cs-137 (HPGe identified) from 0 to 8 feet is erratic indicative of tank farm activities such as transfer line operations.
Grade thickness product from 47 to 62 feet is decreasing consistent with a least squares fit for Co-60 (HPGe identified) and Sb-125 (hypothesis) from 1975 to 1993. The least squares fit results in gross gamma contribution ratio of Sb-125 to Co-60 of 2.10 as of Jan 1975.
Grade thickness product from 62 to 90 feet is decreasing consistent with a least squares fit for Ru-106 (hypothesis) and Co-60 (HPGe identified) from 1975 to 1993. The least squares fit results in gross gamma contribution ratio of Ru-106 to Co-60 of 1.0 as of Jan 1975. Note, the background was least squares fit and subsequently subtracted for this interval grade thickness product.

Gross Gamma Survey Information

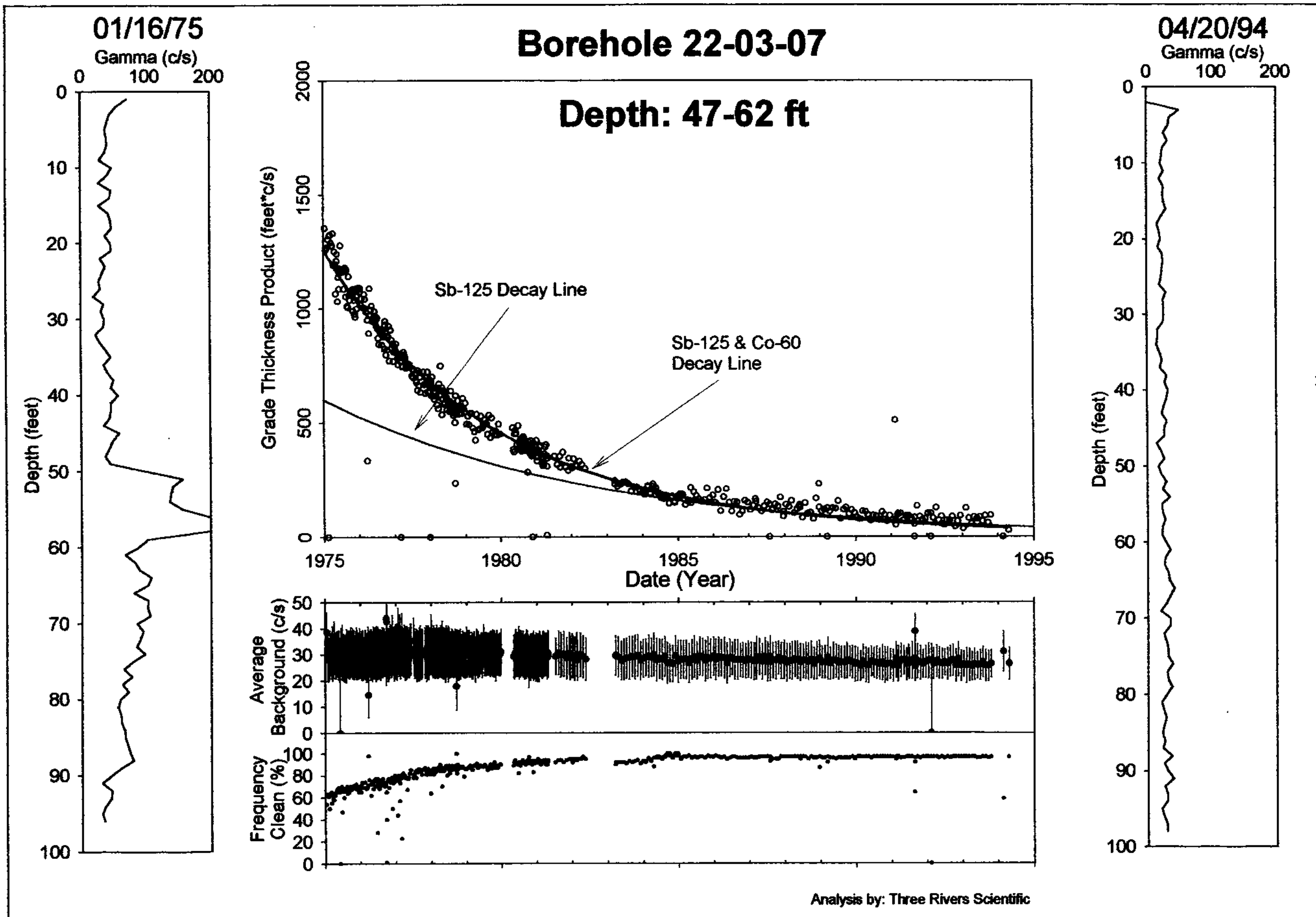
Probe Type :	04: NaI
Other Probe Types :	02: Red GM, 03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/16/1975
Last Survey Date :	4/20/1994
Number Surveys :	475

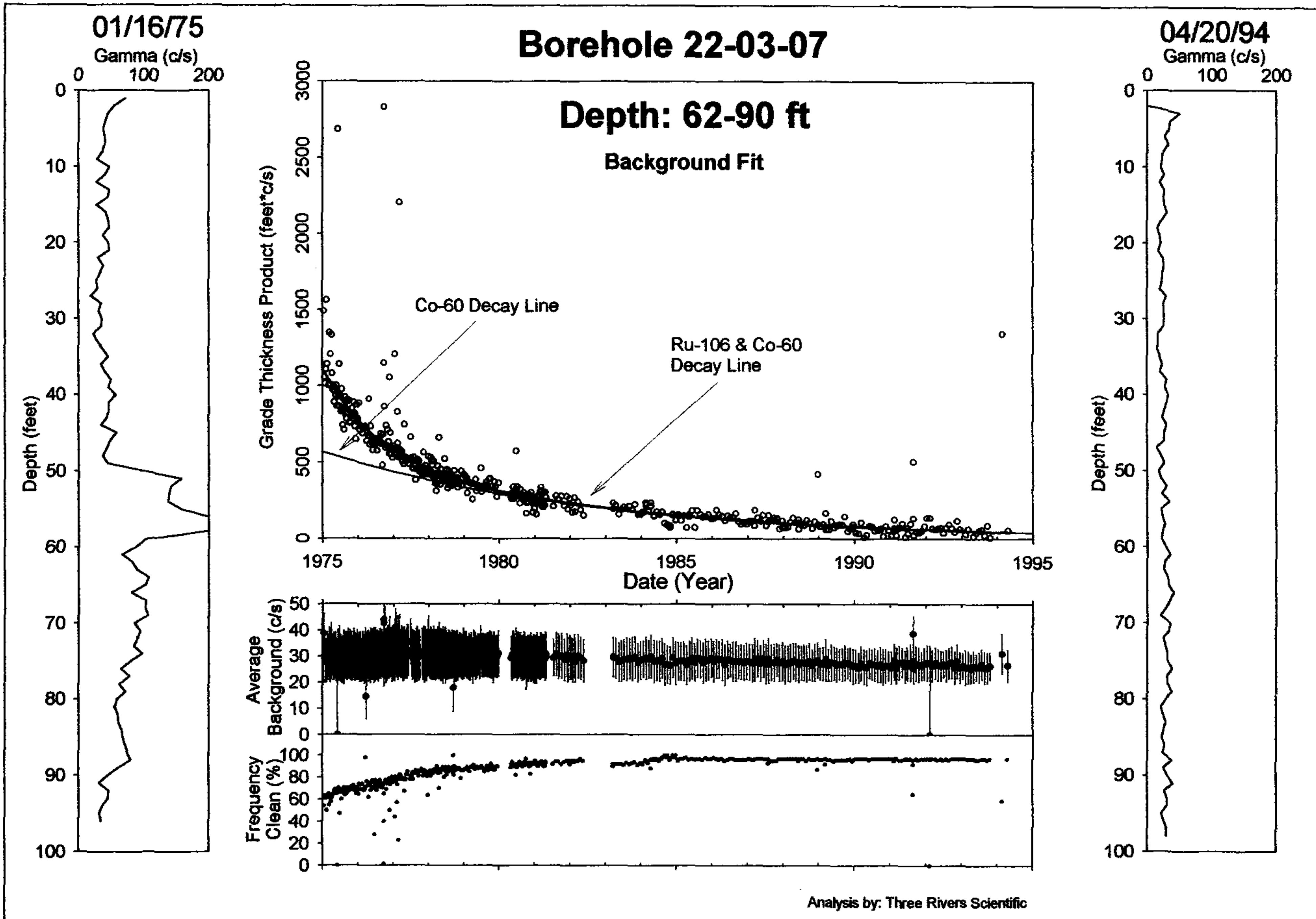
Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50 all zones but 62-90 with least squares fit background	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-8 Tank Farm Activity 47-62 & 62-90 Stable	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	

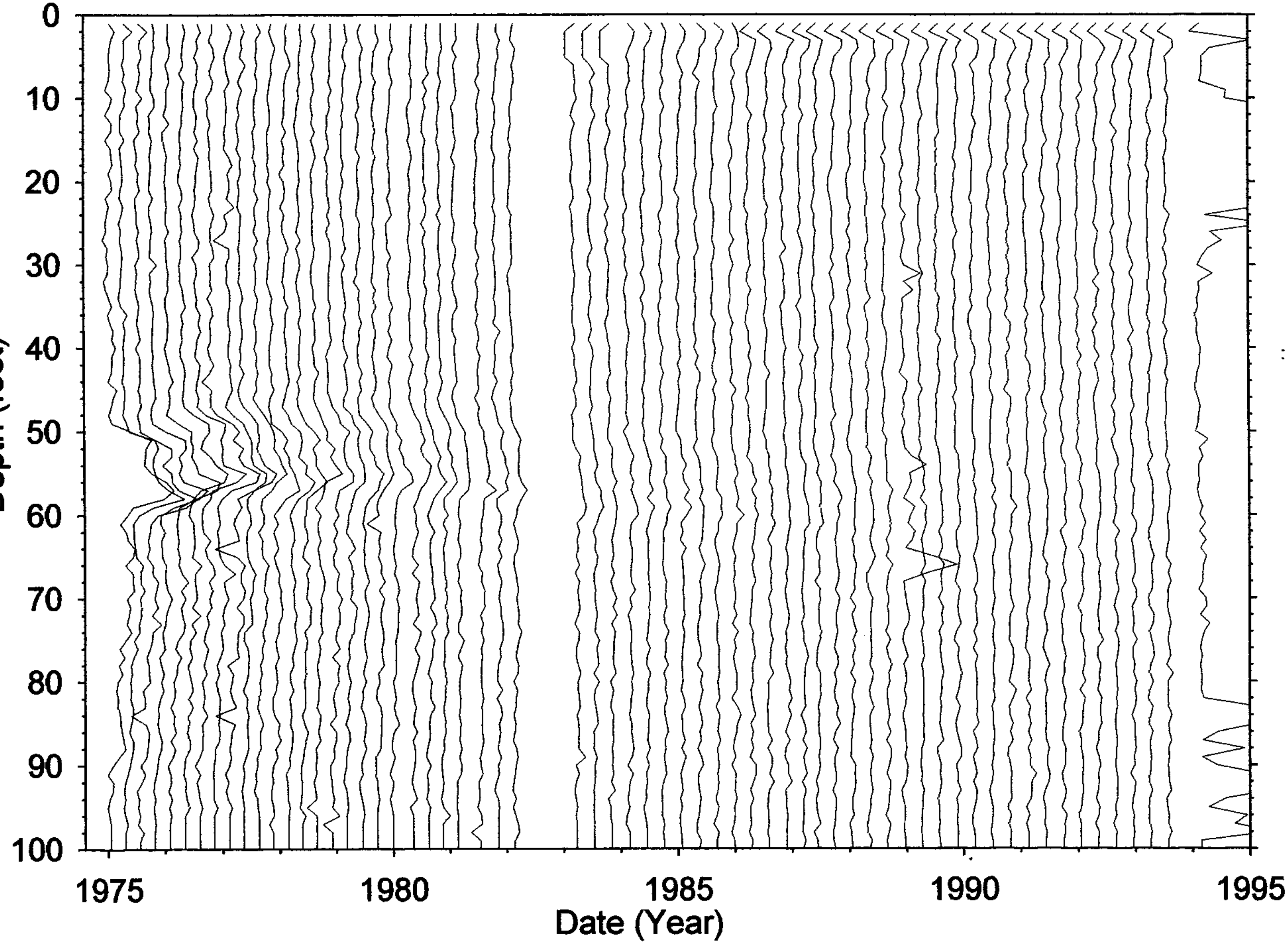

01/16/75
Gamma (c/s)
0
100
200
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
Borehole 22-03-07
Depth: 0-8 ft
Grade Thickness Product (feet*c/s)
0
200
400
600
800
1000
1200
1400
Cs-137 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average Background (c/s)
0
10
20
30
40
50
Frequency Clean (%)
0
20
40
60
80
100
Analysis by: Three Rivers Scientific
04/20/94
Gamma (c/s)
0
100
200
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100

00 170


01/16/75
Gamma (c/s)
0
100
200
Depth (feet)
Borehole 22-03-07
Depth: 47-62 ft
Grade Thickness Product (feet*c/s)
Sb-125 Decay Line
Sb-125 & Co-60
Decay Line
Date (Year)
1975
1980
1985
1990
1995
Average
Background (c/s)
Frequency
Clean (%)
04/20/94
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific


Borehole 22-03-07
Depth: 62-90 ft
Background Fit
01/16/75
Gamma (c/s)
04/20/94
Depth (feet)
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Ru-106 & Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

Borehole 22-03-07



Borehole 22-03-08

Contamination (Cs-137) from 0-8 feet is Tank Farm Activity
Contamination (Co-60 & Ru-106) from 40-60 feet is Stable
Contamination (Co-60) from 80-98 feet appears Stable

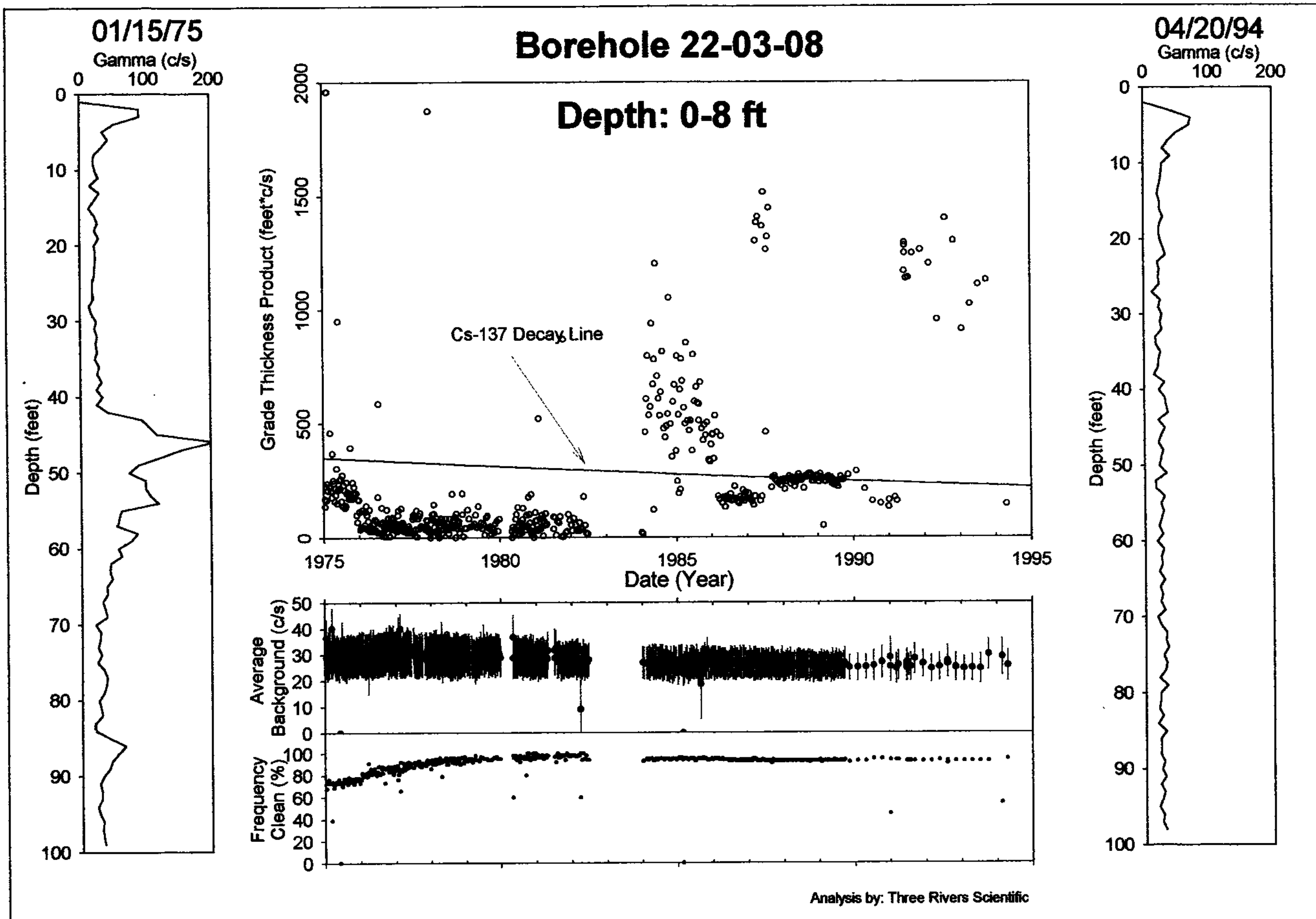
Grade thickness product Cs-137 (HPGe identified) from 0 to 8 feet is erratic indicative of tank farm activities such as transfer line operations.
Grade thickness product from 40 to 60 feet is decreasing consistent with a least squares fit for Co-60 (HPGe identified) and Ru-106 (hypothesis) from 1975 to 1993. The least squares fit results in gross gamma contribution ratio of Ru-106 to Co-60 of 5.92 as of Jan 1975.
Grade thickness product (Co-60) from 80 to 98 feet is decreasing consistent Co-60 (HPGe identified) from 1975 to 1993. The levels are near threshold for gross gamma.

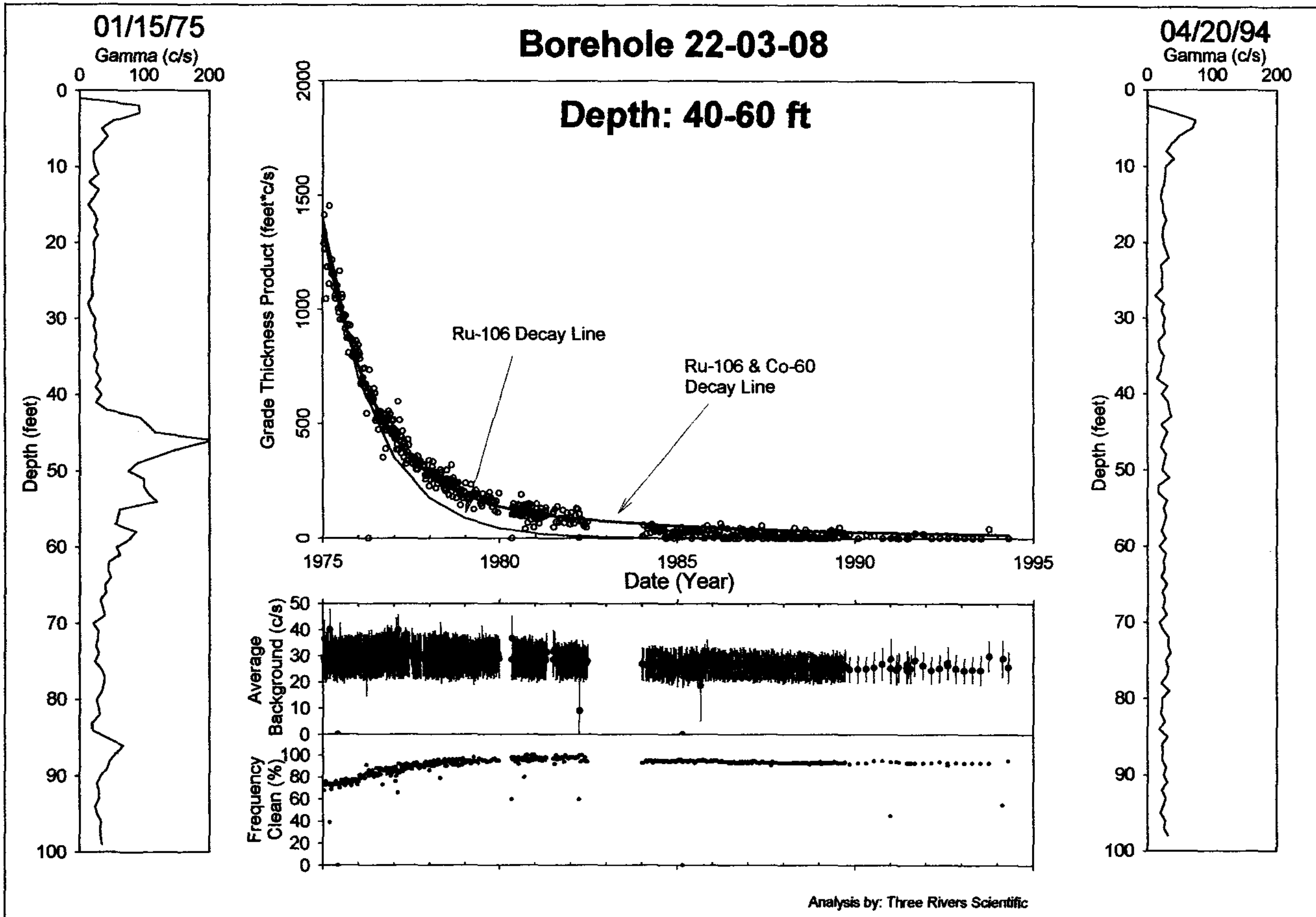
Gross Gamma Survey Information

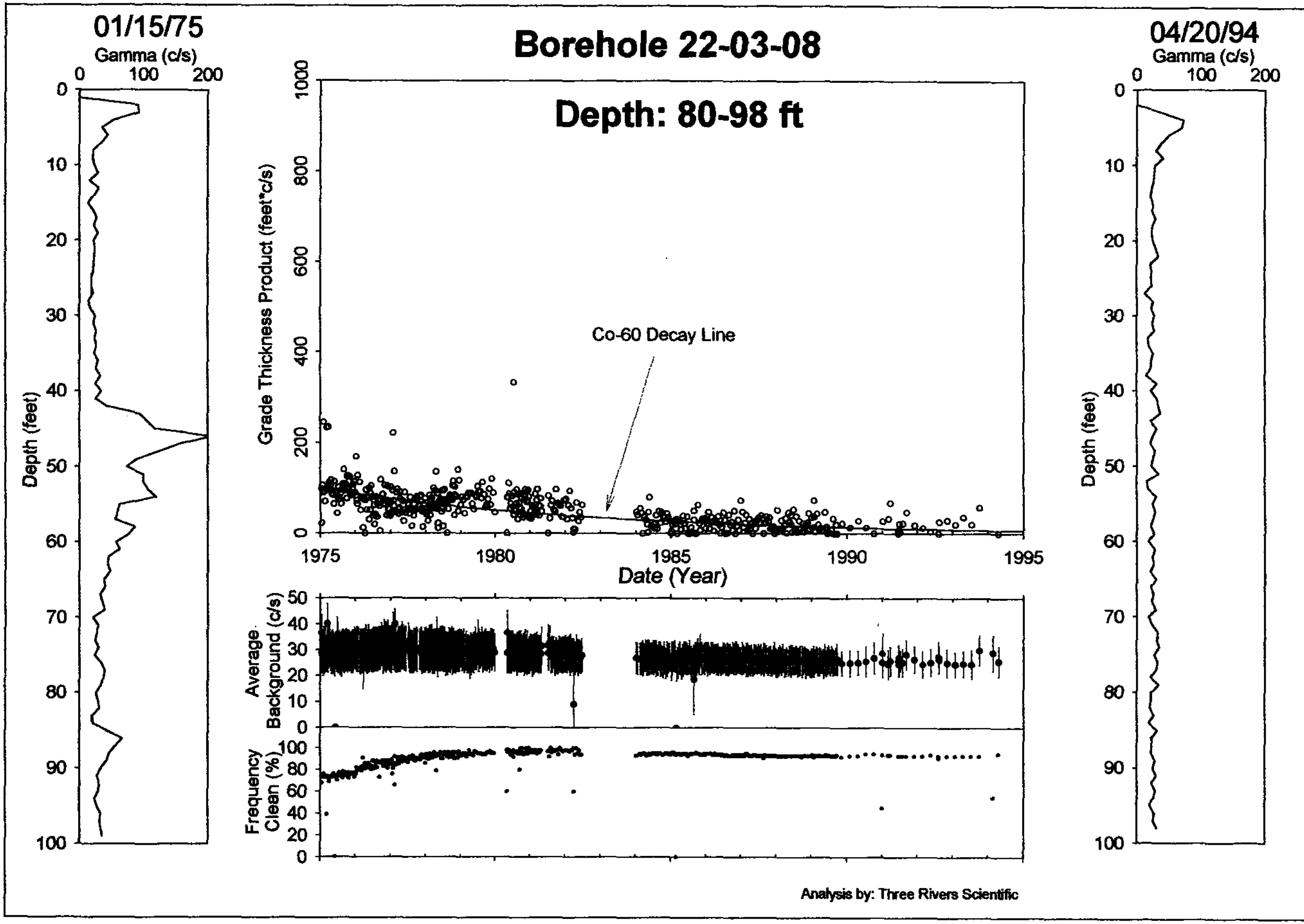
Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/15/1975
Last Survey Date :	4/20/1994
Number Surveys :	504

Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-8 Tank Farm Activity 40-60 & 80-98 Stable	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	


Borehole 22-03-08
Depth: 0-8 ft
01/15/75
04/20/94
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

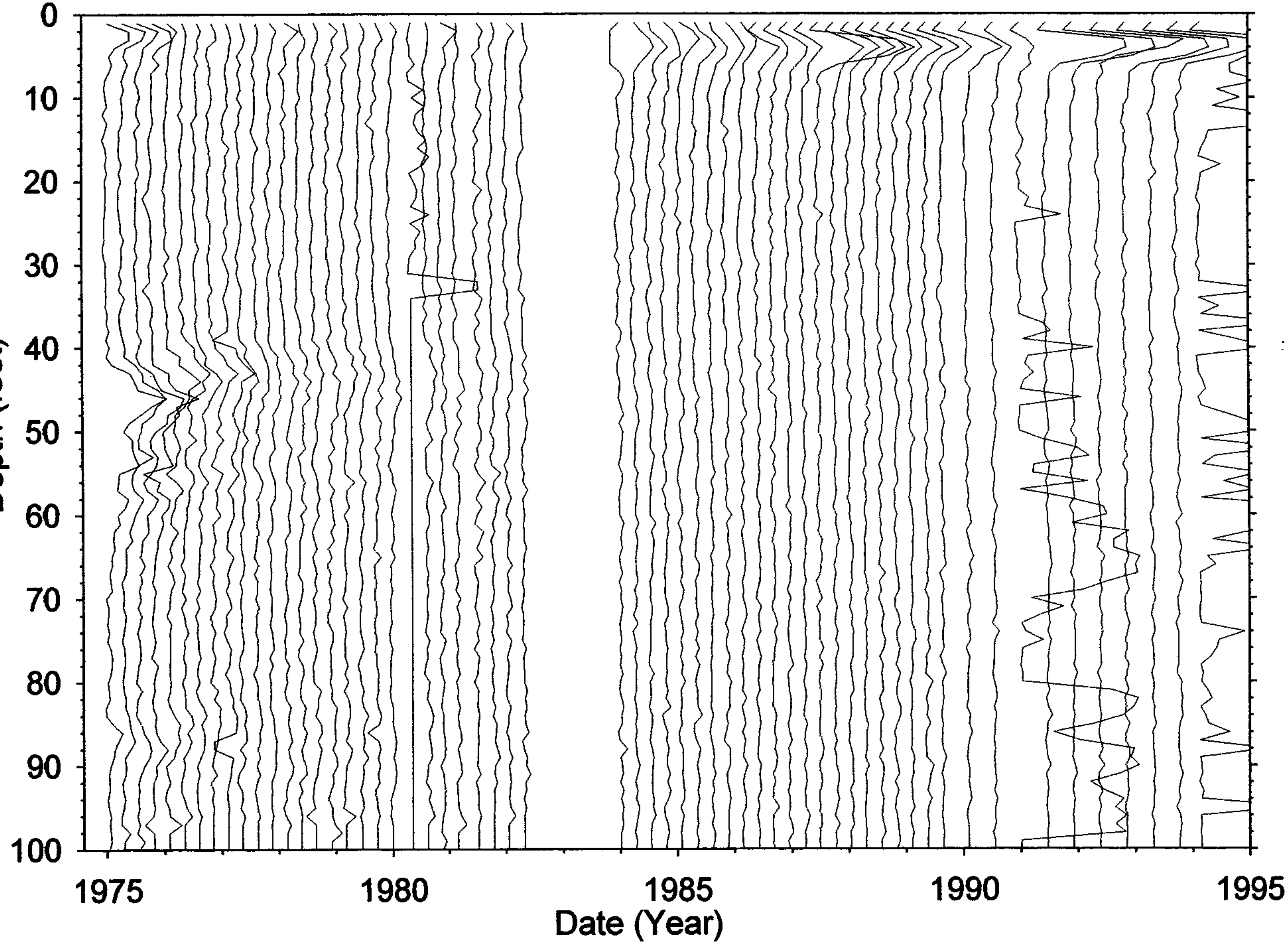

01/15/75
Gamma (c/s)
Depth (feet)
Borehole 22-03-08
Depth: 40-60 ft
Grade Thickness Product (feet*c/s)
Ru-106 Decay Line
Ru-106 & Co-60
Decay Line
Date (Year)
Average
Background (c/s)
Frequency
Clean (%)
Analysis by: Three Rivers Scientific
04/20/94
Gamma (c/s)
Depth (feet)



01/15/75
Gamma (c/s)
Depth (feet)
Borehole 22-03-08
Depth: 80-98 ft
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
04/20/94
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific

00 177

Borehole 22-03-08



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Borehole 22-03-09

Contamination (Cs-137 & Eu-154) from 0-11 feet is Tank Farm Activity
Contamination (Ru-106) from 11-24 feet is Undetermined
Contamination (Ru-106 & Sb-125) from 24-52 feet is Unstable Early
Contamination (Ru-106) from 44-52 feet is Unstable Early
Contamination (Co-60) from 78-82 feet is Unstable Early
Contamination (Co-60) from 48-95 feet has downward Movement*

*During downward movement could be any radionuclide

Grade thickness product Cs-137 (HPGe identified) from 0 to 11 feet is erratic indicative of tank farm activities such as transfer line operations, but also contains Eu-154 (HPGe identified) that shows stable from 1986 to 1994. Note Co-60 HPGe identified) levels are too low to be seen.

The interval from 11 to 52 feet has possible downward movement, refer to stack plot. Thus this interval is broken into several sections, 11-24, 24-52, 44-52, and 11-52 feet. Co-60 and Cs-137 were both identified by HPGe logging system; however, Sb-125 & Ru-106 are hypothesized for some of the intervals. Grade thickness product from 11 to 24 feet is decreasing nearly consistent with Ru-106 (hypothesis) and the HPGe identified Cs-137 is to low to register. Depth errors may cause the small deviation observed, but due to possible downward movement depth correction is not computed. Grade thickness product from 24-52 feet follows a least squares fit for Sb-125 & Ru-106 (both hypothesized) after initial increase and fixing from1975 through 1977. Given these radionuclides, the gross gamma contribution ratio of Sb-125 to Ru-106 is 0.23 in Jan 1975. If the upper zone from 11-24 is Ru-106, then the increase from 1975 to 1977 for 24-52 feet is lateral. Grade thickness product from 44 to 52 feet is observed for the structure from 1984 to 1994. Before 1984, there is possible downward movement into this zone, but after 1984 the possibility of fixing in this bed exists. Given the isotope is Ru-106, then the interval is stable after 1984. May be a case for downward movement to a fixing zone. The entire zone from 11-52 feet has the dominant character of 24-52 feet, and stable after 1977 for Sb-125 and Ru-106. Therefore, the total conserved radionuclides are stable within this encompassing zone and any downward movement is confined to this total depth interval. The least squares fit results for the gross gamma contribution ratio of Sb-125 to Ru-106 is 0.20 in Jan 1975.

The interval from 48 to 95 feet is chosen in order to view the clearly downward moving front and avoid depth control problems. An attempt to process a grade thickness product over this interval to cover all the downward movement range is not possible since the movement is below the borehole depth. However, the interval from 48 to 95 feet should cover all downward movement from 1975 to mid 1985, and over this time there is no stability. This indicates lateral influx as well as the downward migration. An Sb-125 decay curve (hypothesis) is shown over a possible early (and thus stable) time from 1976 to 1978. The Sb-125 may have been stable and still not register on the HPGe due to detection thresholds, but could have also been remobilized and flushed from the zone. Final note, from 1991 to 1994 the interval appears to be stable Co-60

Borehole 22-03-09

(HPGe identified), which indicates a residual left behind. Likewise, the interval from 78-82 feet may be a lense that retained Co-60 after the front moved down. Thus the grade thickness plot

for 78-82 feet should be viewed from about 1987 to 1994. Over this time, the interval does match the Co-60 (HPGe identified) suggesting fixed Co-60 after passage of the front. Note that in 1975 the front covered this thin zone, therefore, it is possible this fixed Co-60 was in place before the front moved through. The front in this entire interval is moving at a rate near 2 ft/year downward. Given this rate is maintained, then the present leading ledge of the front is now (Aug 1998) at a depth of 122 feet.

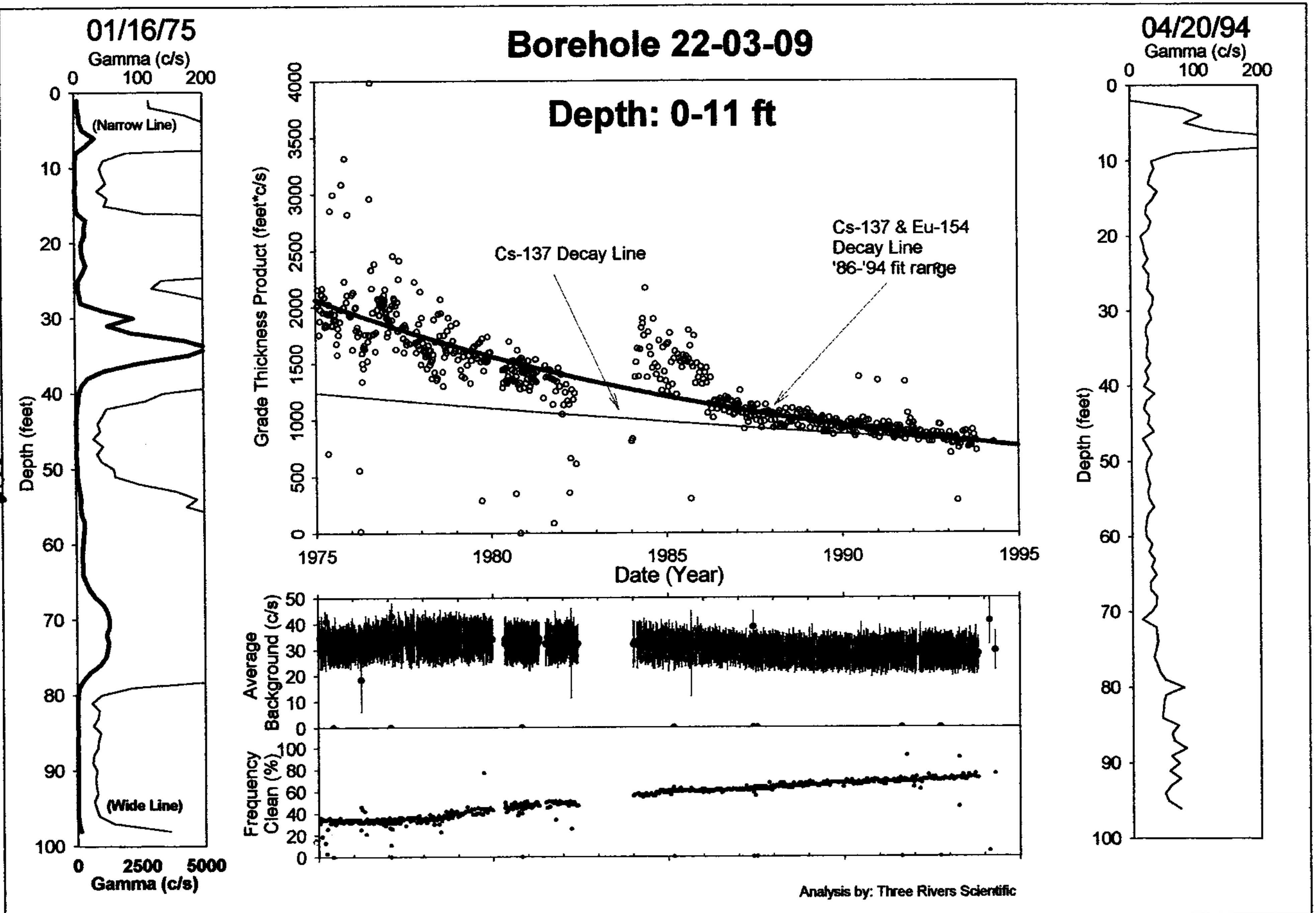
During instability, no identification of isotopes is possible, and any one or combination may in fact be the mobile species.

Gross Gamma Survey Information

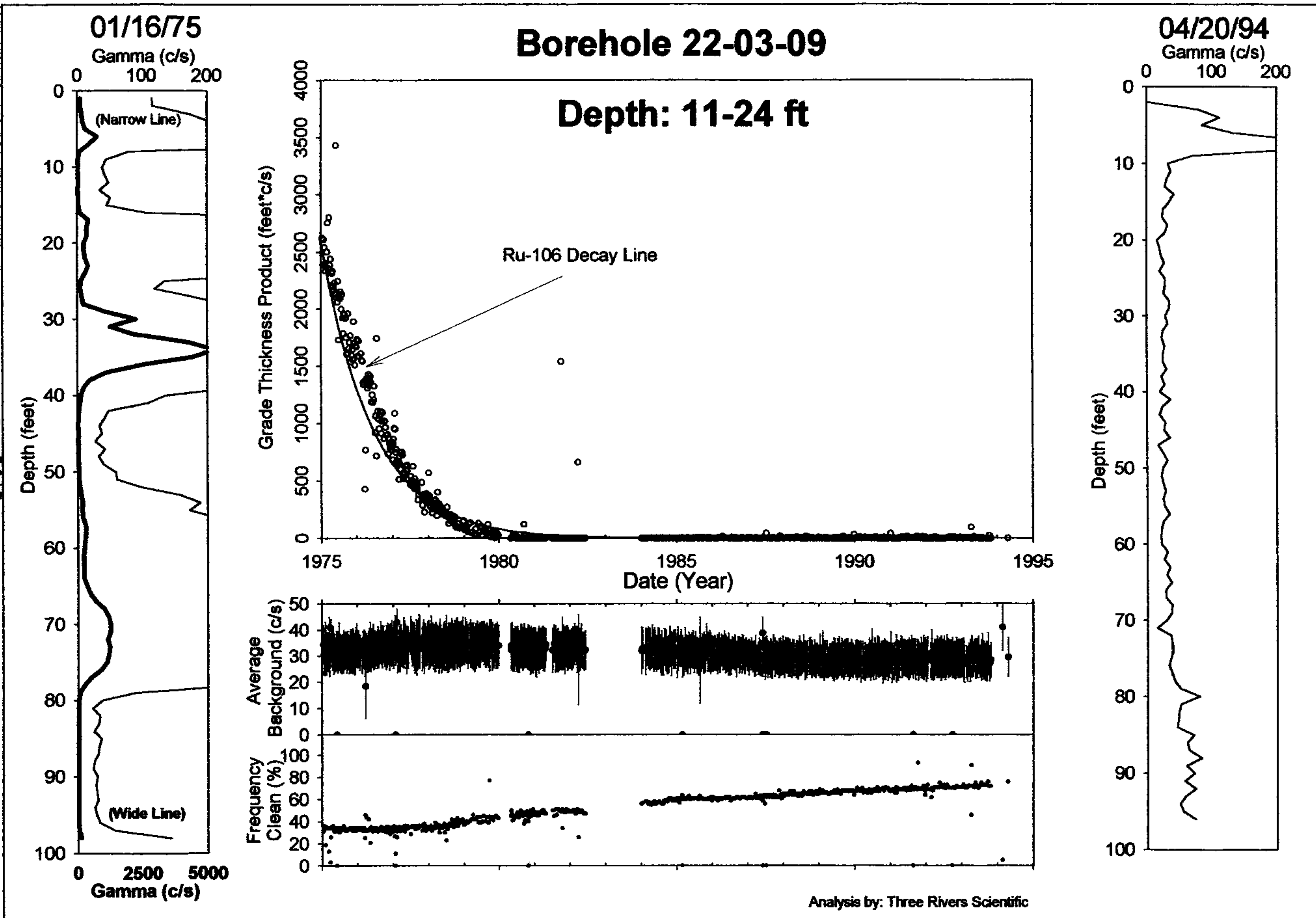
Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/16/1975
Last Survey Date :	4/20/1994
Number Surveys :	618

Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50 all zones but 24-52 with least squares fit background	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-11 Tank Farm Activity 11-24 Undetermined 24-52 & 44-52 & 78-82 Unstable Early 48-95+ Downward Movement	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	



01/16/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Borehole 22-03-09
Depth: 0-11 ft
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Cs-137 & Eu-154
Decay Line
'86-'94 fit range
Date (Year)
Average
Background (c/s)
Frequency
Clean (%)
Analysis by: Three Rivers Scientific
04/20/94
Gamma (c/s)
Depth (feet)



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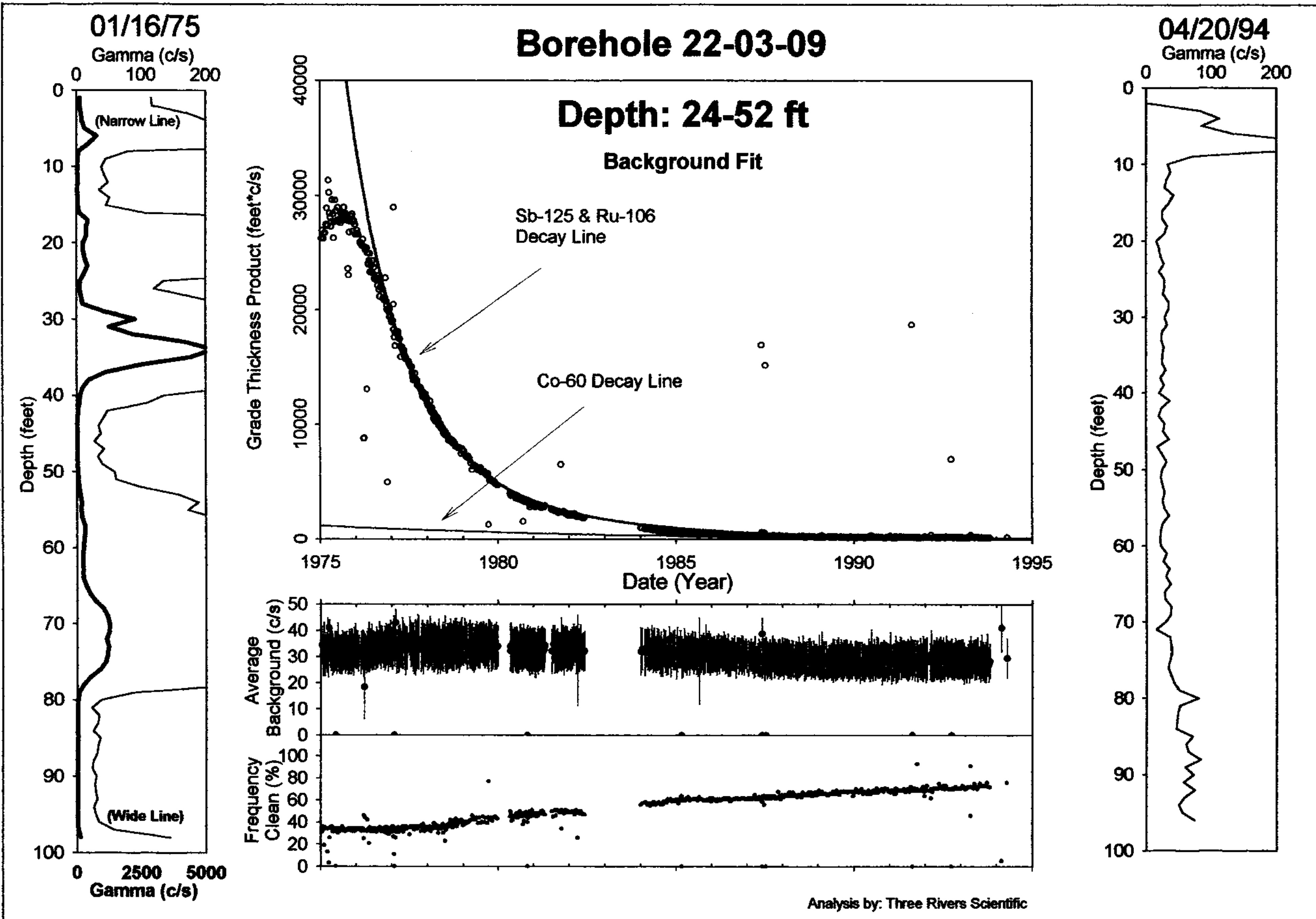
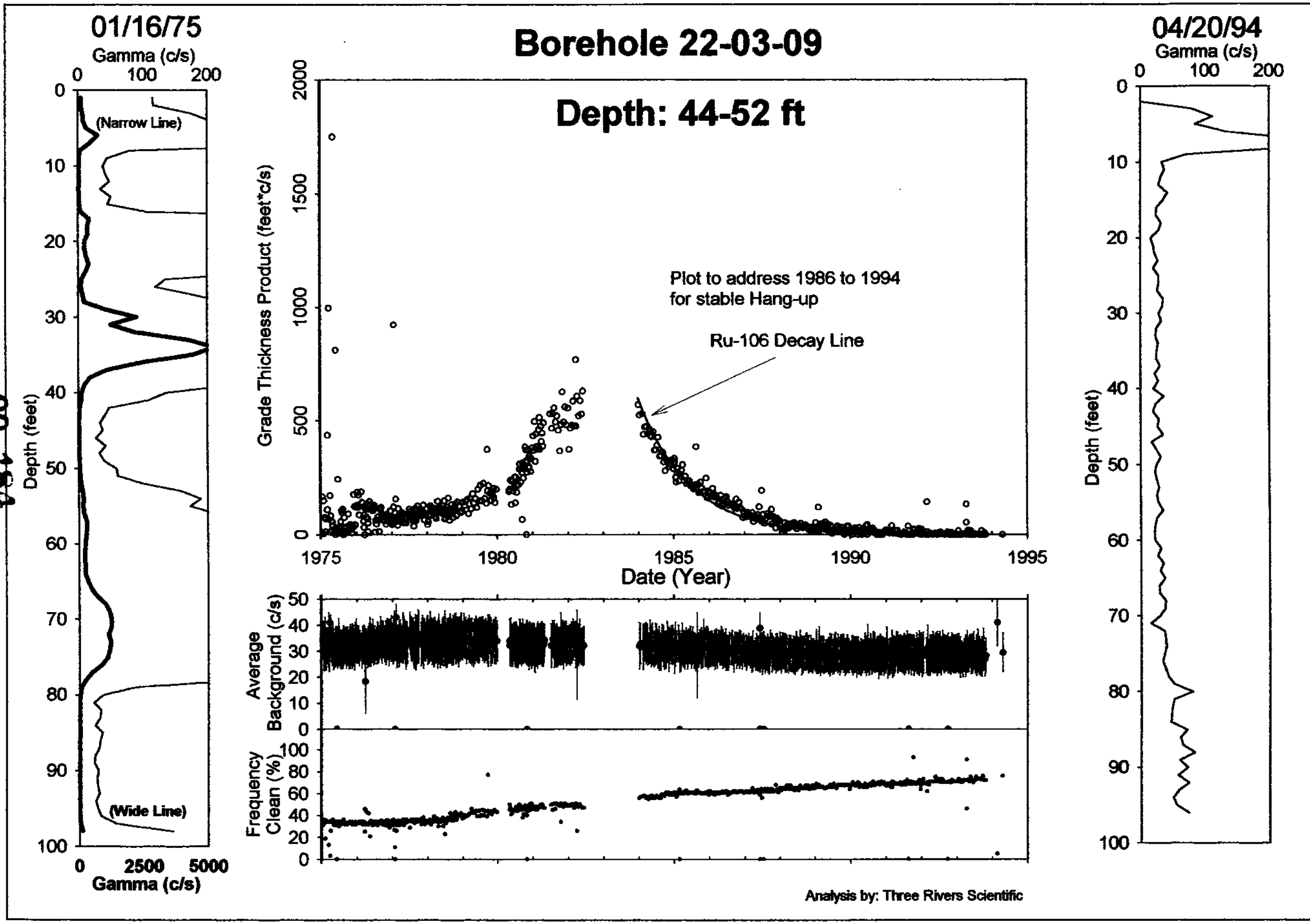
00 182

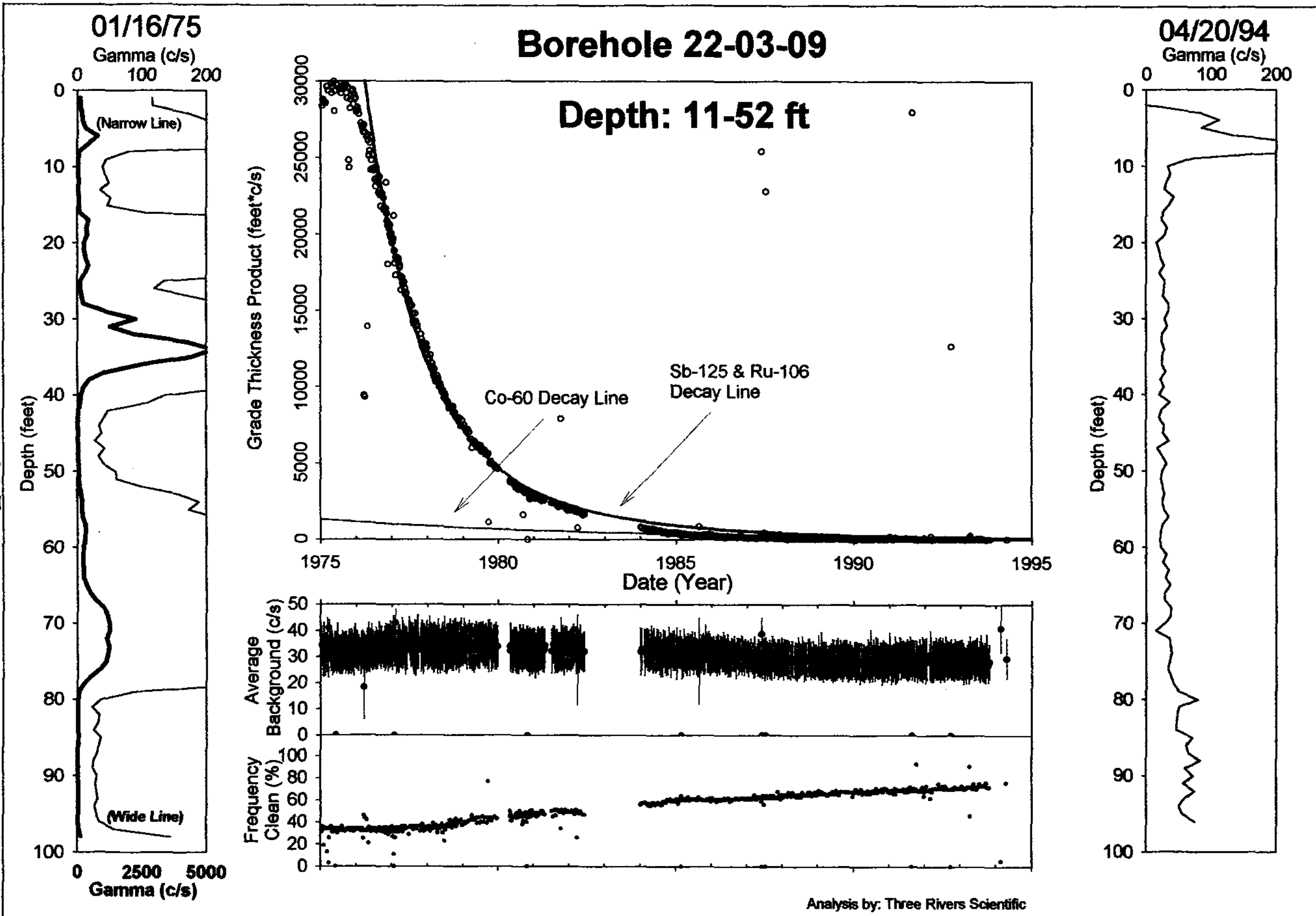


Borehole 22-03-09
Depth: 24-52 ft
Background Fit
01/16/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Sb-125 & Ru-106 Decay Line
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
04/20/94
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific

00 183



01/16/75
Gamma (c/s)
0
100
200
(Narrow Line)
(Wide Line)
Depth (feet)
0
2500
5000
Gamma (c/s)
Borehole 22-03-09
Depth: 44-52 ft
Grade Thickness Product (feet*c/s)
Plot to address 1986 to 1994
for stable Hang-up
Ru-106 Decay Line
Date (Year)
1975
1980
1985
1990
1995
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
04/20/94
Gamma (c/s)
Depth (feet)



00 185

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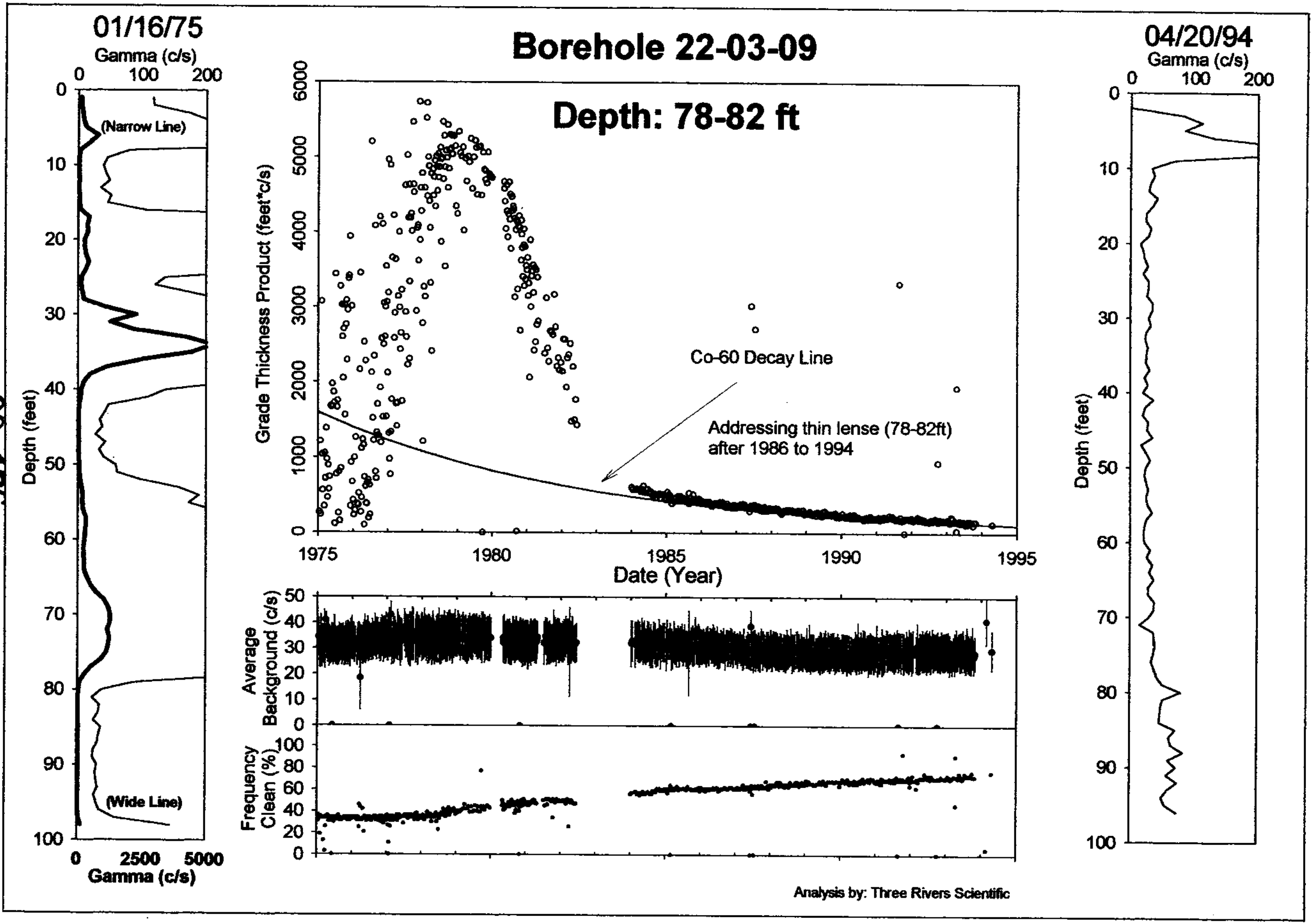
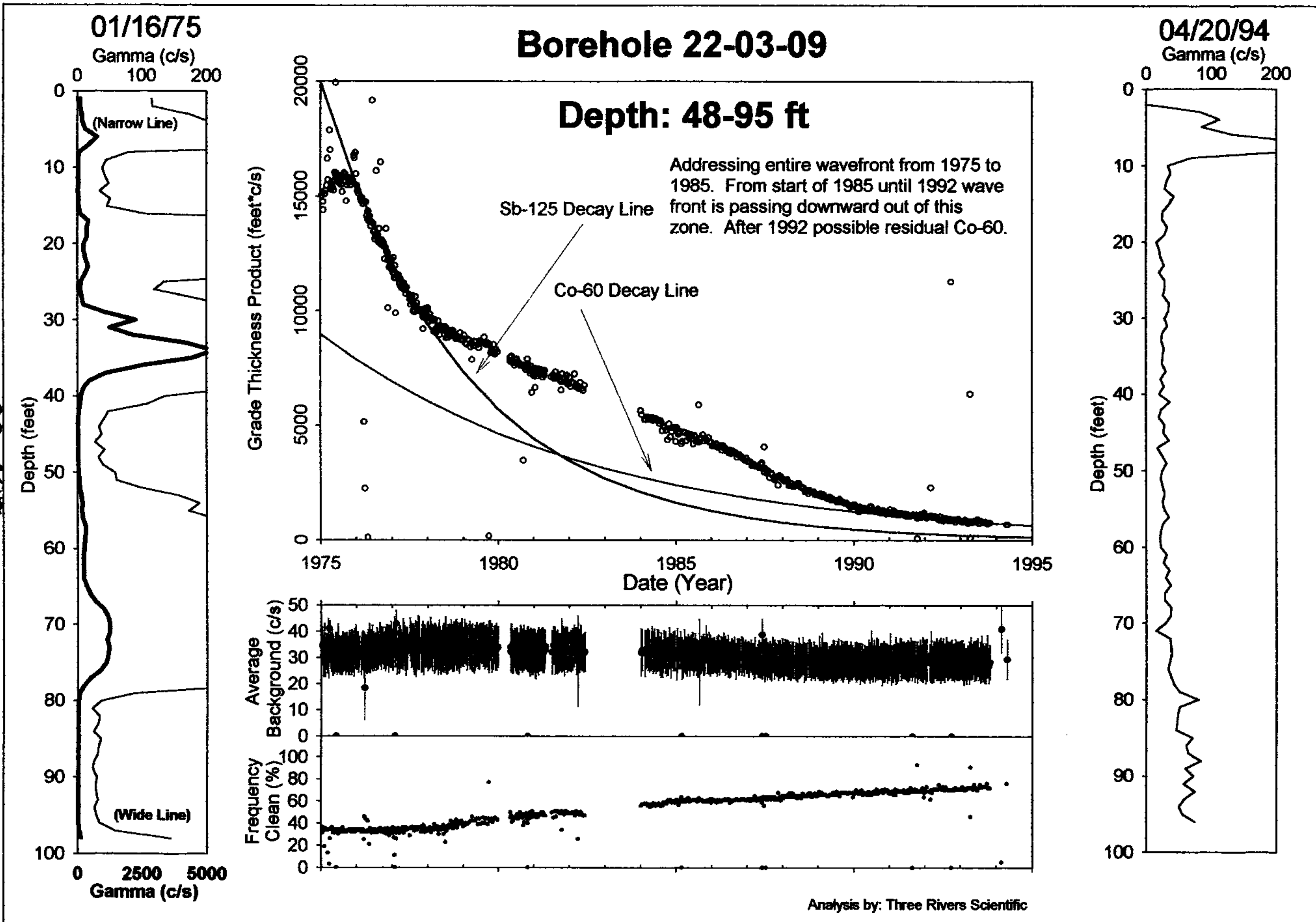
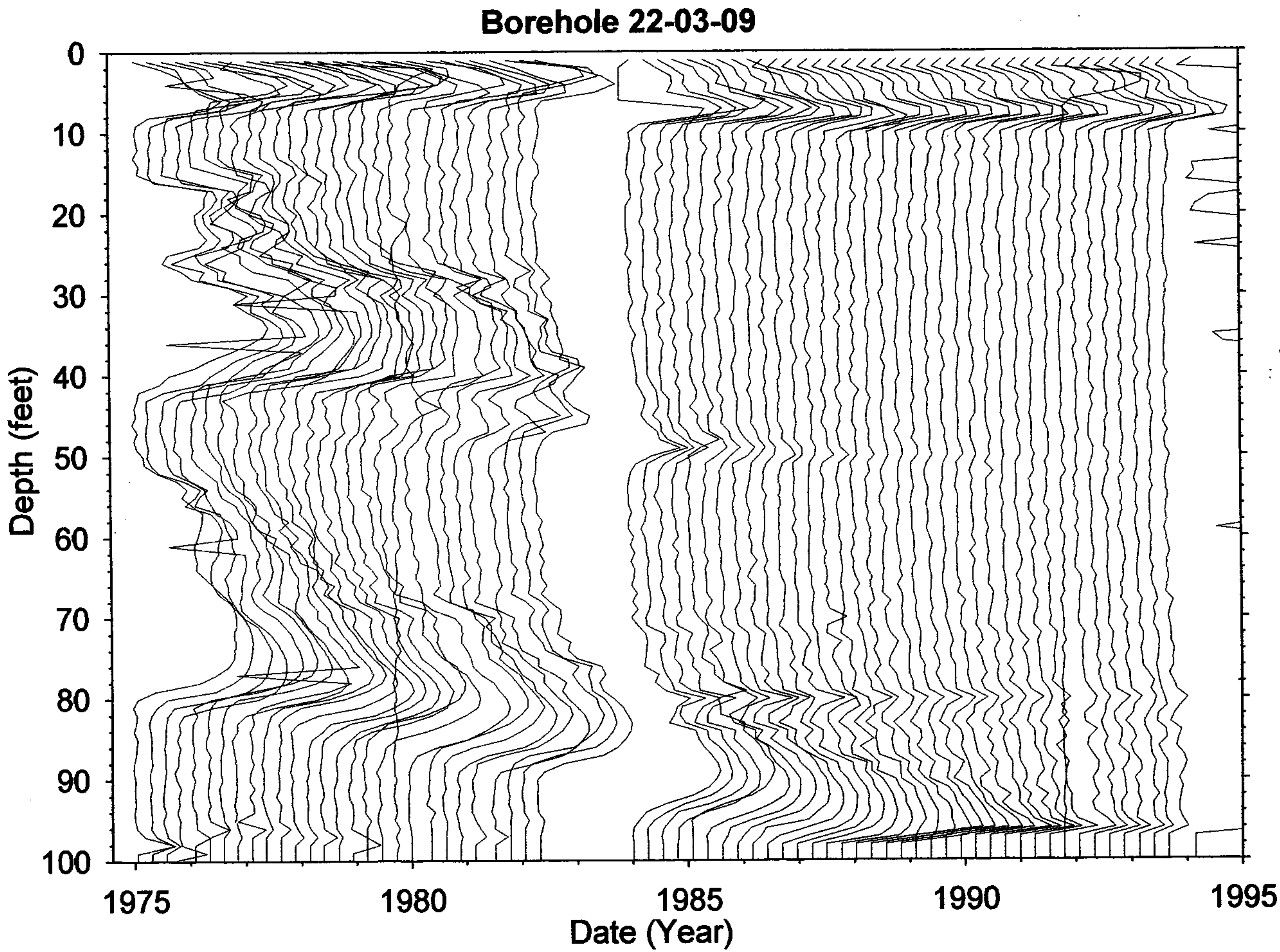


HNF-3532 -REV0

00 186



HNF-3532 -REV0



HNF-3532 -REV0

Borehole 22-03-10

Contamination (Cs-137) from 0-8 feet is Tank Farm Activity
Contamination (Cs-137) from 8-30 feet is Stable

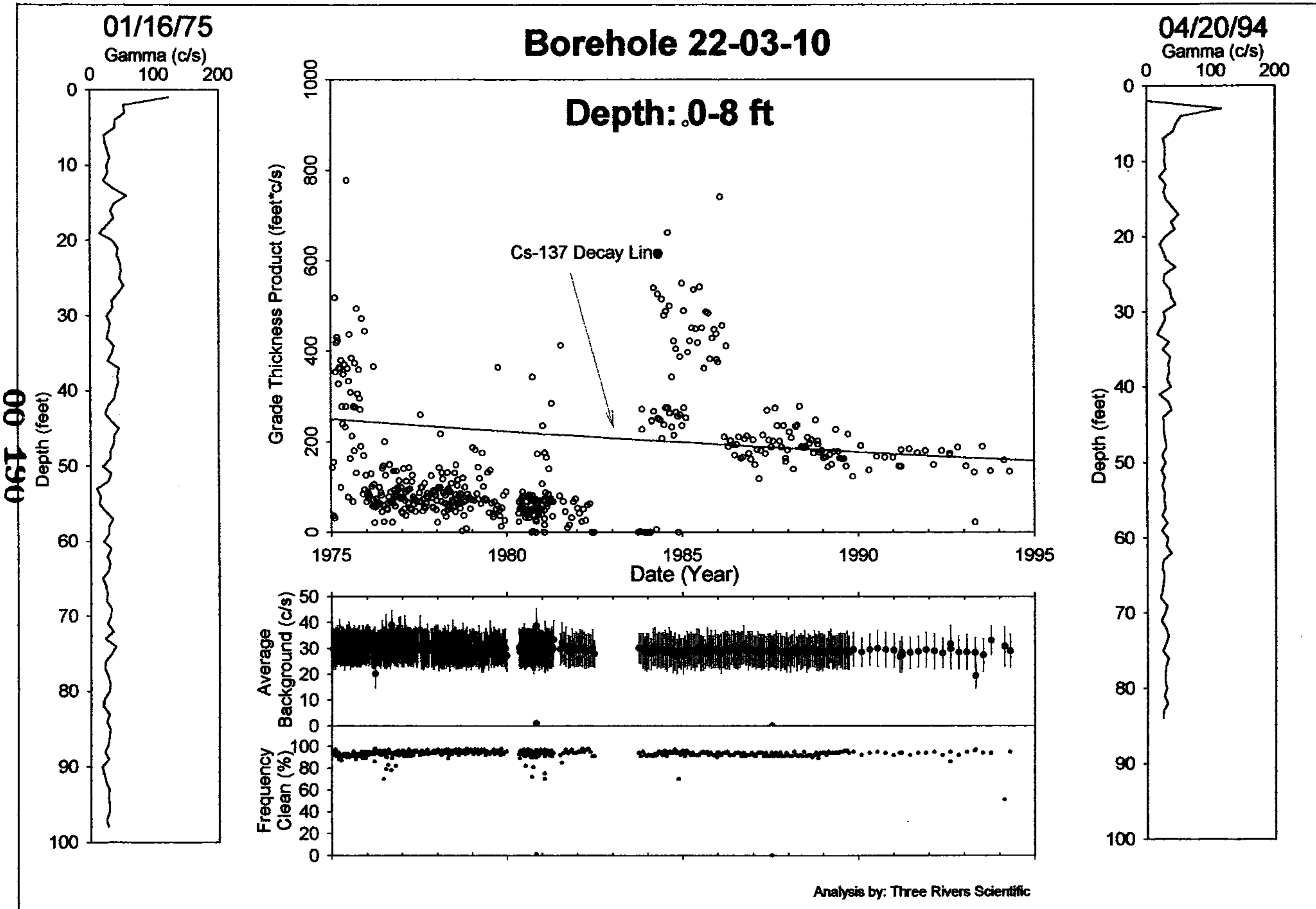
Grade thickness product Cs-137 (HPGe identified) from 0 to 8 feet is erratic indicative of tank farm activities such as transfer line operations.
Grade thickness product from 8 to 30 feet is decreasing consistent with Cs-137 (HPGe identified) 1975 to 1994. The activity levels are near threshold for the gross gamma logging system.

Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft 1975 85 ft from 1980-1994
Survey Depth :	100 ft 1975 85 ft from 1980-1994
First Survey Date :	1/16/1975
Last Survey Date :	4/20/1994
Number Surveys :	472

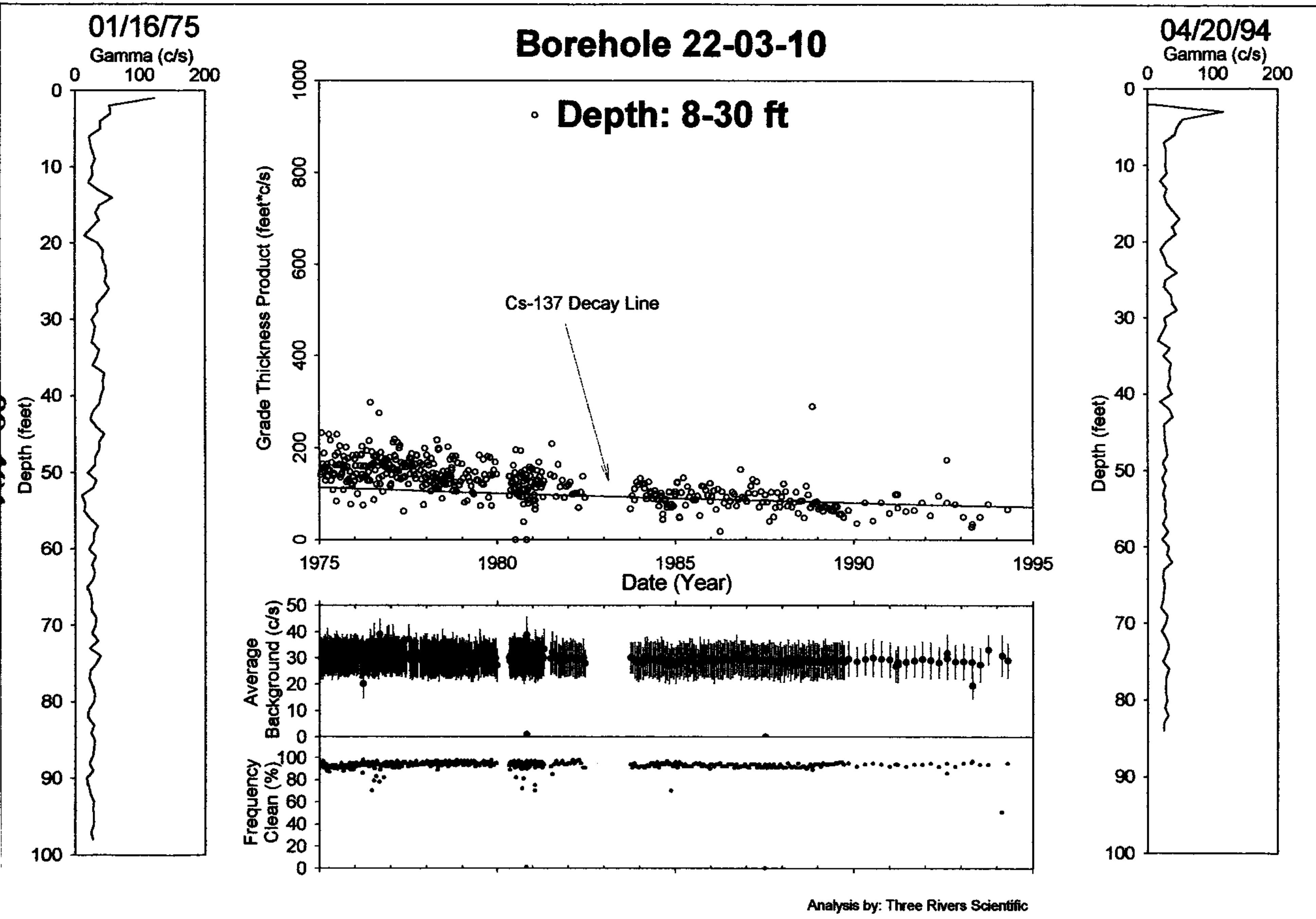
Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-8 Tank Farm Activity 8-30 Stable	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	



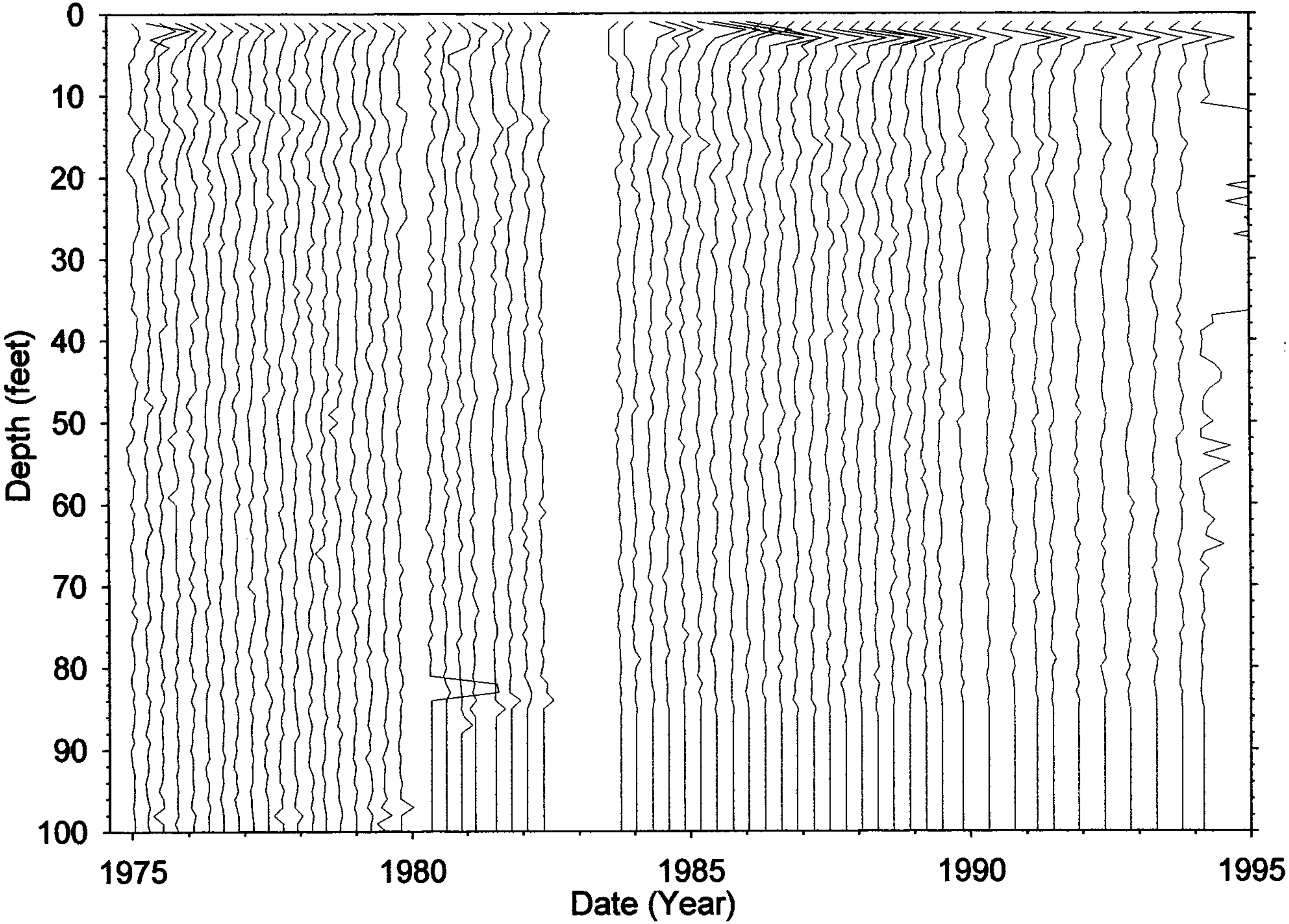
00 190

HNF-3532 -REV0



Borehole 22-03-10
Depth: 8-30 ft
01/16/75
Gamma (c/s)
Depth (feet)
04/20/94
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

Borehole 22-03-10



Dry Well Survey Analysis - Notes

Borehole 22-03-01
Total # Surveys 547
Probe Type 04 02
neutron surveys 7
GR Surveys 538
Log Date: 1-16-75 1st
4-22-94 Last
Presentation Plot Dates ____
(If different from 1st & Last)

Contamination Zone Depth(s): ____
Isotope from Spectral Survey: Cs low @ surface
Max Survey Depth 95

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			0-10 intermittent

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Analyst Name [signature]
S/W ver IFGROSS 2-2

filein := "two.txt"
15-95 feet

Well 21-03-01

Special study in low grade Cs over all well depths and sensitivity to background.

A := READPRN(filein)

$yr := A^{\langle 1 \rangle}$ $net := A^{\langle 7 \rangle}$ $bkg := A^{\langle 6 \rangle}$ $max := A^{\langle 4 \rangle}$

$N := \mathrm{last}(yr)$ $N = 515$ $i := 0..N$ $k := 0..300$ $j := 0..299$ $\tau eu := 30.17$

$\tau co := 5.27$ $\tau cs := 3 \cdot 10^9$ $aco := 00$ $acs := 1600$

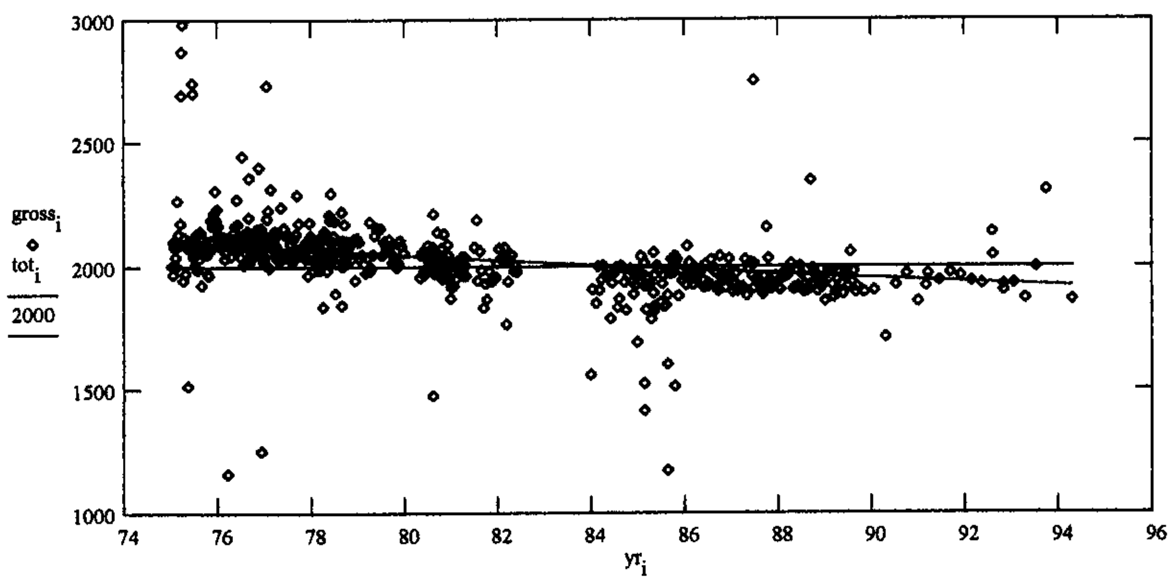
Eu variables are Ru-106 $aeu := 500$

$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1$ $tot_i := Cs_i + Eu_i$

$gross_i := net_i$

Cs variables are U238

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

$ssq(acs, aeu) = 0$ $1 = 1$

$$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := \mathrm{Minerr}(acs, aeu)$$

$\alpha cs = 1.562 \cdot 10^3$ U-238 $\alpha eu = 532.09$ Sb-125

$\frac{\alpha cs}{\alpha eu} = 2.935$

$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $tot_i := Cs_i + Eu_i$

$out^{\langle 0 \rangle} := yr$ $out^{\langle 1 \rangle} := tot$ WRITEPRN("twop.txt") := out $\frac{Eu_N}{Cs_N} = 0.219$

Dry Well Survey Analysis - Notes

BY

Borehole 22-03-04 Total # Surveys 466 Probe Type 04

\# neutron surveys 9 # GR Surveys 457

Log Date: 1-16-75 1st 4-20-94 Last Presentation Plot Dates ______

(If different from 1st & Last)

Contamination Zone Depth(s): ______

Isotope from Spectral Survey: Co and Sb Co Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			same zones as HPGe
			use Stack to pick intervals

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Analyst Name Ross Randall S/W ver TFGROSS22

filein := "two55-85.txt" **Well 21-03-04**

A := READPRN(filein) $yr := A^{\langle 1\rangle}$ $net := A^{\langle 7\rangle}$ $bkg := A^{\langle 6\rangle}$ $max := A^{\langle 4\rangle}$

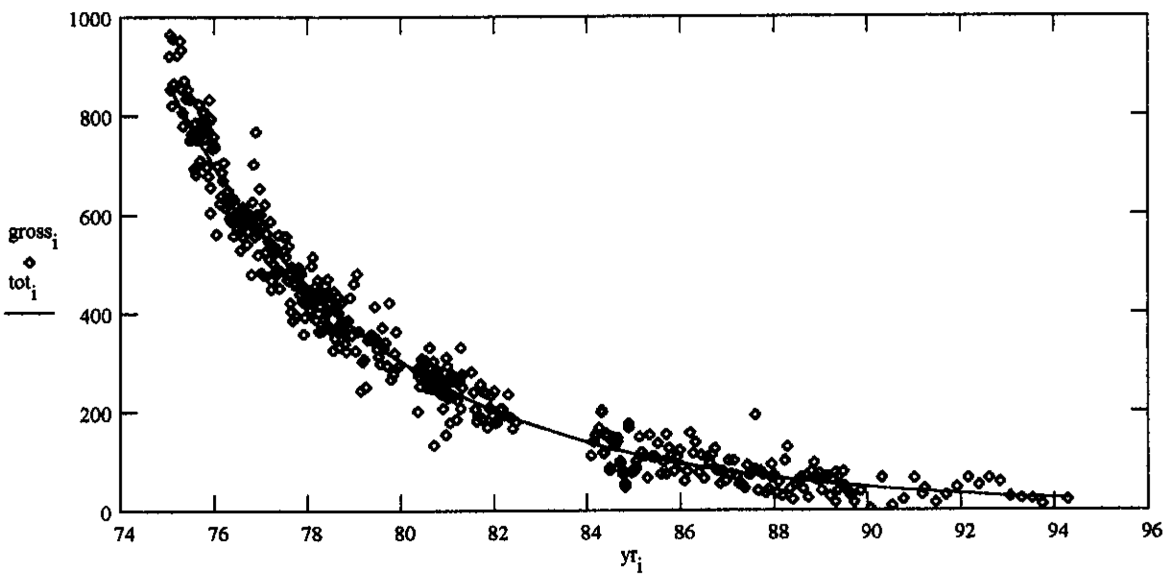
N := last(yr) N = 435 i := 0 .. N k := 0 .. 300 j := 0 .. 299 τeu := 2.77

τco := 5.27 τcs := 5.27 aco := 00 acs := 230 Eu variables are Ru-106 aeu := 640

$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1$ $tot_i := Cs_i + Eu_i$

$gross_i := net_i$ Cs variables are U238

This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

ssq(acs, aeu) = 0 1 = 1

$$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := Minerr(acs, aeu)$$

αcs = 229.704 αeu = 638.998
Co-60 Sb-125

$\frac{\alpha cs}{\alpha eu} = 0.359$

$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $tot_i := Cs_i + Eu_i$

$out^{\langle 0\rangle} := yr$ $out^{\langle 1\rangle} := tot$ WRITEPRN("twop.txt") := out $\frac{Eu_N}{Cs_N} = 0.281$

80-88

Dry Well Survey Analysis - Notes

BY

'80-89 |
235-238 RKP 37 |

Borehole 22-03-05 Total # Surveys 532 Probe Type 01 02 04 14

\# neutron surveys 4 # GR Surveys ______

Log Date: 7-24-80 1st (01) 11-8-89 Last Presentation Plot Dates ______
(If different from 1st & Last)

Contamination Zone Depth(s): ______

Isotope from Spectral Survey: Cs high(Sat) Co Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			1 any 8-16 20-60 60-90
			Not stack for zones character

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

0-5 5-15 15-60 60-85

5-5-80 & 11-8-89 for 02 tool
some surveys in set 02 are really 01

Analyst Name Ronald Randall S/W ver TFGROSS 2.2

Dry Well Survey Analysis - Notes

BY

Borehole 22-03-06

Total # Surveys 496

Probe Type 04

neutron surveys 6

GR Surveys ~~[illegible]~~ 490

Log Date: 1-16-78 1st

4-20-94 Last

Presentation Plot Dates

(If different from 1st & Last)

Contamination Zone Depth(s):

Isotope from Spectral Survey: Cs Co Sb

Cs/gross not consistent

Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			Lot of activity recorded depth steps
			Stack for gross
			0-10 20-28 37-48
			48-60 60-94 94-105

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Rapid gross as Sb on 40-48

Cs not scale with gross near surface

37-48 zone required Background in LSQ fit refer to Mathcad file. This fit result was then subtracted from GTF for plot presentation

Analyst Name [illegible signature]

S/W ver TFGRASS 2.2

filein := "two37-48.txt" **Well 21-03-06**

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

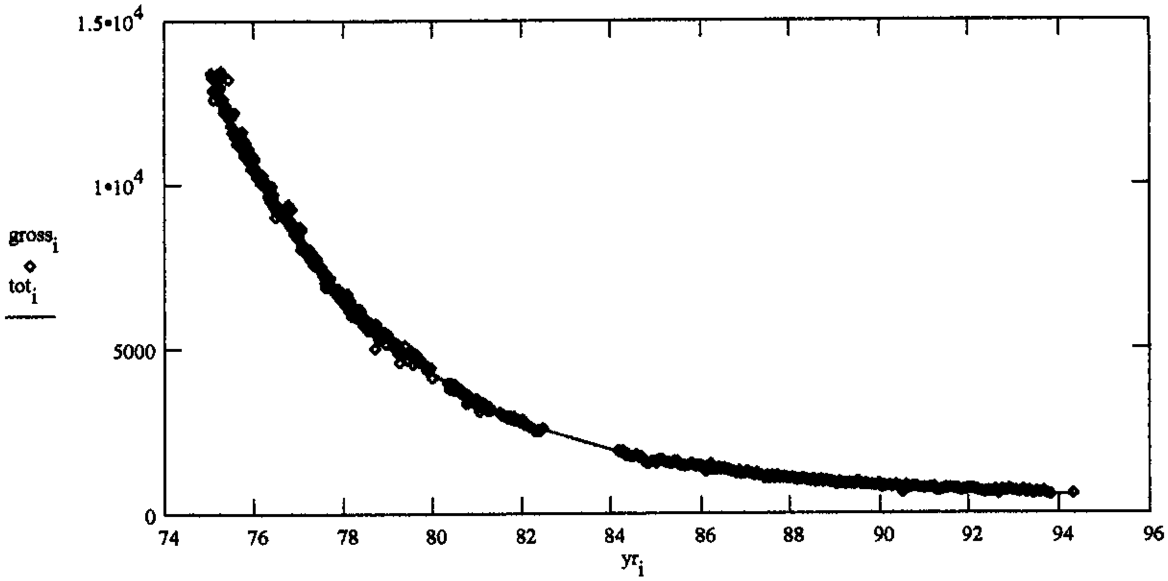
N := last(yr) N = 472 i := 0..N k := 0..300 j := 0..299 $\tau eu := 2.77$

$\tau co := 5.27$ $\tau cs := 30.17$ aco := 80 acs := 690 Eu variables are Ru-106 aeu := 12650

$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1$ $tot_i := Cs_i + Eu_i + C$

$gross_i := net_i$ Cs variables are U238

This data edited for spurious points



$$ssq(a1,a3,a2) := \sum_i \left[gross_i - \left[a1\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + \left[a3\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} + a2\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}\right]\right]\right]^2$$

Given

ssq(acs, aeu, aco) = 0 1 = 1 2 = 2

$$\begin{bmatrix}\alpha cs\\ \alpha eu\\ \alpha co\end{bmatrix} := \text{Minerr}(acs, aeu, aco)$$

$\alpha cs = 689.623$ U-238 $\alpha eu = 1.265\cdot10^4$ Sb-125 $\alpha co = 79.7$

$\frac{\alpha cs}{\alpha eu} = 0.055$

$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $Co_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$

$\frac{Eu_N}{Cs_N} = 0.228$

$tot_i := Cs_i + Eu_i + Co_i$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop37-48.txt") := out

filein := "two48-60.txt" **Well 21-03-06**

A := READPRN(filein) $yr := A^{\langle 1 \rangle}$ $net := A^{\langle 7 \rangle}$ $bkg := A^{\langle 6 \rangle}$ $max := A^{\langle 4 \rangle}$

$\tau eu := 2.77$

N := last(yr) N = 473 i := 0 .. N k := 0 .. 300 j := 0 .. 299

$\tau co := 1$ $\tau cs := 30.17 \cdot 10^9$ aco := 500 acs := -60

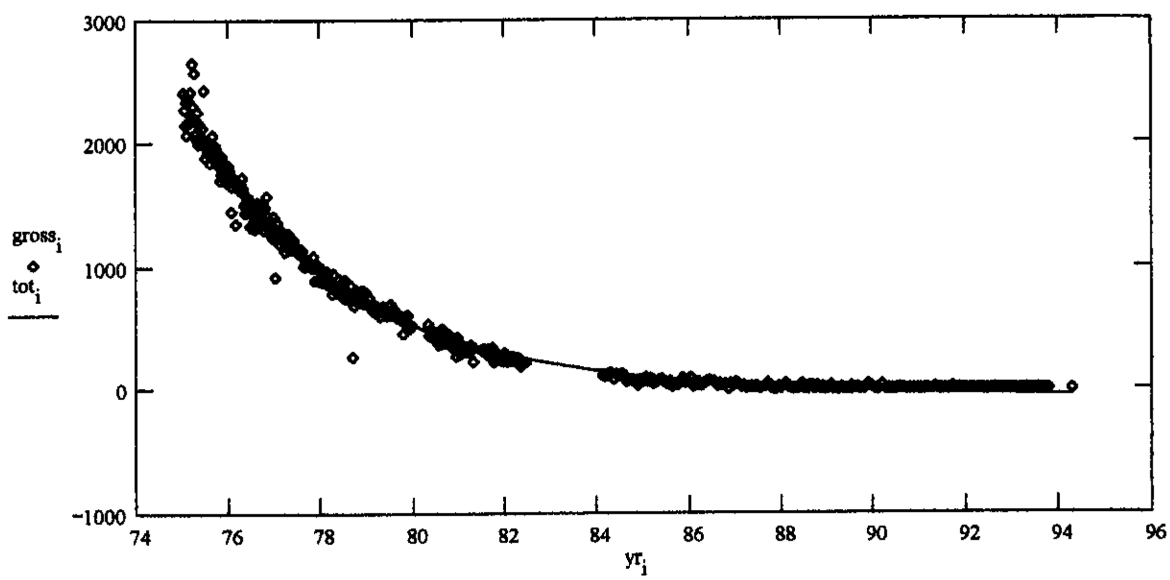
Eu variables are Ru-106 aeu := 2000

$Cs_i := acs \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau eu}} \cdot 1$ $tot_i := Cs_i + Eu_i + C$

$gross_i := net_i$

Cs variables are U238

This data edited for spurious points



bkg := -50

$$ssq(a1, a3, bkg) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau co}} + \left[a3 \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau eu}} + bkg \right] \right] \right]^2$$

Given

ssq(aco, aeu, bkg) = 0 1 = 1 2 = 2

$$\begin{bmatrix} \alpha co \\ \alpha eu \\ Bkg \end{bmatrix} := Minerr(aco, aeu, bkg)$$

Bkg = −59.013 Background | $\alpha eu = 1.998 \cdot 10^3$ Sb-125 | $\alpha co = 501.47$ Ru-106

$Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau eu}}$ $Co_i := \alpha co \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau co}}$

$\frac{Eu_N}{Cs_N} = -0.266$

$tot_i := Bkg + Eu_i + Co_i$

Negative background from overstripping

$out^{\langle 0 \rangle} := yr$ $out^{\langle 1 \rangle} := tot$ WRITEPRN("threep48-60.txt") := out filein := "two60-94b.txt" **Well 21-03-06** Includes bkg, i.e. no background subtraction

$A := \mathrm{READPRN}(filein)$ $yr := A^{\langle 1\rangle}$ $net := A^{\langle 7\rangle}$ $bkgrkp := A^{\langle 6\rangle}$ $max := A^{\langle 4\rangle}$ $b := 34\cdot 28.1$

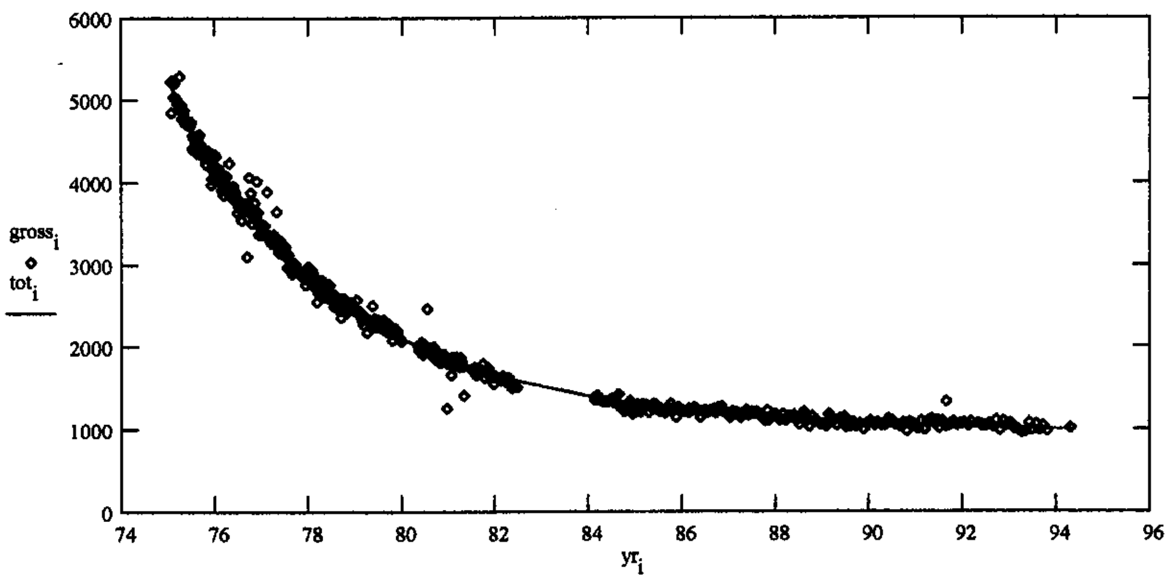
$N := \mathrm{last}(yr)$ $N = 470$ $i := 0..N$ $k := 0..300$ $j := 0..299$ $\tau eu := 2.77$

$\tau co := 5.27$ $\tau cs := 1$ $aco := 299$ $acs := 581$ Eu variables are Sb-125 $aeu := 3440$

$Cs_i := acs\cdot e^{-(yr_i-75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco\cdot e^{-(yr_i-75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu\cdot e^{-(yr_i-75)\cdot\frac{\ln(2)}{\tau eu}}\cdot 1$ $tot_i := Cs_i + Eu_i + Co_i +$

$gross_i := net_i$ Cs variables are Ru-106

This data edited for spurious points



$$ssq(a1,a3,a2,b) := \sum_i\left[gross_i - \left[a1\cdot e^{-(yr_i-75)\cdot\frac{\ln(2)}{\tau co}} + \left[a3\cdot e^{-(yr_i-75)\cdot\frac{\ln(2)}{\tau eu}} + a2\cdot e^{-(yr_i-75)\cdot\frac{\ln(2)}{\tau cs}} + b\right]\right]\right]^2$$

Given

$ssq(aco,aeu,acs,b) = 0$ $1 = 1$ $2 = 2$ $3 = 3$

$$\begin{bmatrix}\alpha co\\ \alpha eu\\ \alpha cs\\ bkg\end{bmatrix} := \mathrm{Minerr}(aco,aeu,acs,b)$$

$\alpha cs = 581$ Ru-106 $\alpha eu = 3.44\cdot 10^3$ Sb-125 $\alpha co = 299$ Co-60

$Cs_i := \alpha cs\cdot e^{-(yr_i-75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu\cdot e^{-(yr_i-75)\cdot\frac{\ln(2)}{\tau eu}}$ $Co_i := \alpha co\cdot e^{-(yr_i-75)\cdot\frac{\ln(2)}{\tau co}}$

$\frac{\alpha co}{\alpha eu} = 0.087$ $\boxed{bkg = 955.4 \text{ Fit background}}$

$\frac{Eu_N}{Cs_N} = 3.056\cdot 10^4$ $\frac{955.4}{35\,FT} = 27.3$ cl. BKG

$tot_i := bkg + Eu_i + Co_i + Cs_i$

$out^{\langle 0\rangle} := yr$ $out^{\langle 1\rangle} := tot$ WRITEPRN("twop60-94Bkg.txt") := out

Dry Well Survey Analysis - Notes

Borehole 22-03-07
Total # Surveys 483
Probe Type 04 02
neutron surveys 7
GR Surveys 475
Log Date: 1-16-75 1st
4-20-94 Last
Presentation Plot Dates ____
(If different from 1st & Last)

Contamination Zone Depth(s): ____
Isotope from Spectral Survey: Cs Co
Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			2 separate dup zone zone by end
			from 47-62 62-90 0-8

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Analyst Name [signature]
S/W ver TFGROSS22

filein := "two47-62.txt" **Well 21-03-07**

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

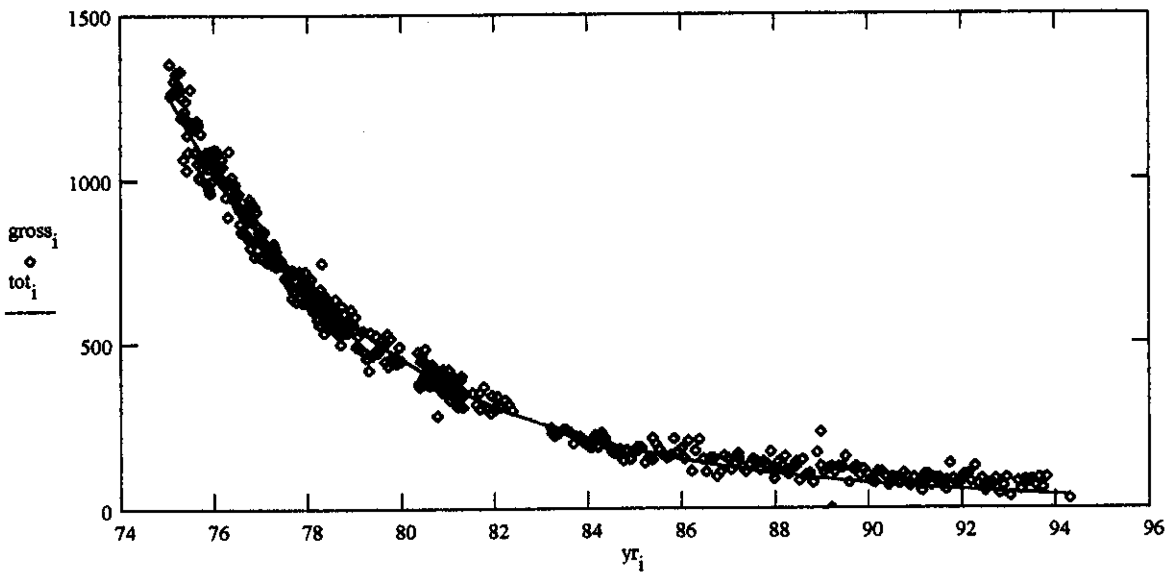
$N := last(yr)$ $N = 460$ $i := 0..N$ $k := 0..300$ $j := 0..299$ $\tau eu := 2.77$

$\tau co := 5.27$ $\tau cs := 3\cdot 10^9$ $aco := 408$ $acs := 00$ Eu variables are Ru-106 $aeu := 856$

$Cs_i := acs\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}\cdot 1$ $tot_i := Co_i + Eu_i$

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

$ssq(aco, aeu) = 0$ $1 = 1$

$\begin{bmatrix} \alpha co \\ \alpha eu \end{bmatrix} := Minerr(aco, aeu)$ $\alpha co = 407.175$ Co-60 $\alpha eu = 856.208$ Sb-125

$Co_i := \alpha co\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := \alpha eu\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $tot_i := Co_i + Eu_i$ $\frac{\alpha co}{\alpha eu} = 0.476$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop47-62.txt") := out $\frac{Eu_N}{Co_N} = 0.213$

filein := "two62-90B.txt" **Well 21-03-07**

$A := READPRN(filein)$ $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$ $B := 28\cdot 28$

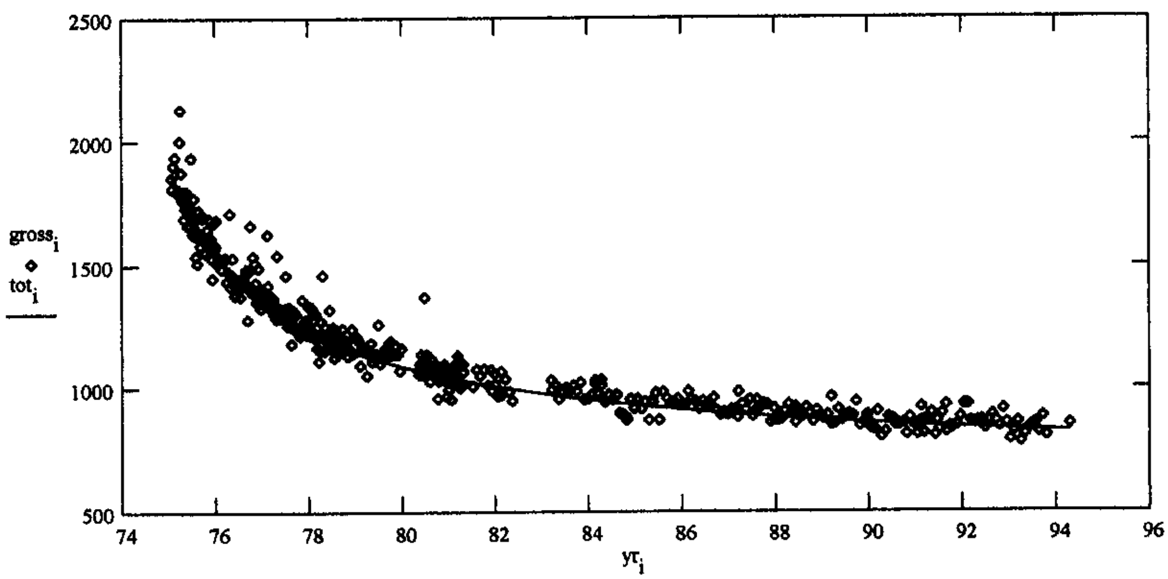
$N := last(yr)$ $N = 455$ $i := 0..N$ $k := 0..300$ $j := 0..299$ $\tau eu := 1$

$\tau co := 5.27$ $\tau cs := 3\cdot 10^9$ $aco := 558$ $acs := 00$ Eu variables are Ru-106 $aeu := 562$

$Cs_i := acs\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}\cdot 1$ $tot_i := Co_i + Eu_i + B$

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1,a3,B) := \sum_i \left[gross_i - \left[a1\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} + B \right] \right]^2$$

Given

$ssq(aco,aeu,B)=0$ $1=1$ $2=2$

$\begin{bmatrix} \alpha co \\ \alpha eu \\ Bkg \end{bmatrix} := Minerr(aco,aeu,B)$

$\alpha co = 572.423$ Co-60 $\alpha eu = 548.753$ Ru-106 $Bkg = 798.926$

$\frac{Bkg}{28} = 28.533$

$\frac{\alpha co}{\alpha eu} = 1.043$

$Co_i := \alpha co\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := \alpha eu\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $tot_i := Co_i + Eu_i + Bkg$

$\frac{Eu_N}{Co_N} = 1.878\cdot 10^{-5}$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop62-90.txt") := out

$Co_N = 45.202$

$tot_N - 799 = 45.129$

BY

Dry Well Survey Analysis - Notes

Borehole 22-03-08 Total # Surveys 510 Probe Type 04

\# neutron surveys 6 # GR Surveys 504

Log Date: 1-15-75 1st 4-20-94 Last Presentation Plot Dates ______ (If different from 1st & Last)

Contamination Zone Depth(s): ______

Isotope from Spectral Survey: Co amf Co ~50 & 90-100 Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			40-60 strong 80-90 weak
			surface

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

From stack ~~#~~ 0-8 40-60 80-95

Analyst Name Rance Randall S/W ver TFGRASS 2.2

filein := "two40-60.txt" **Well 21-03-08**

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

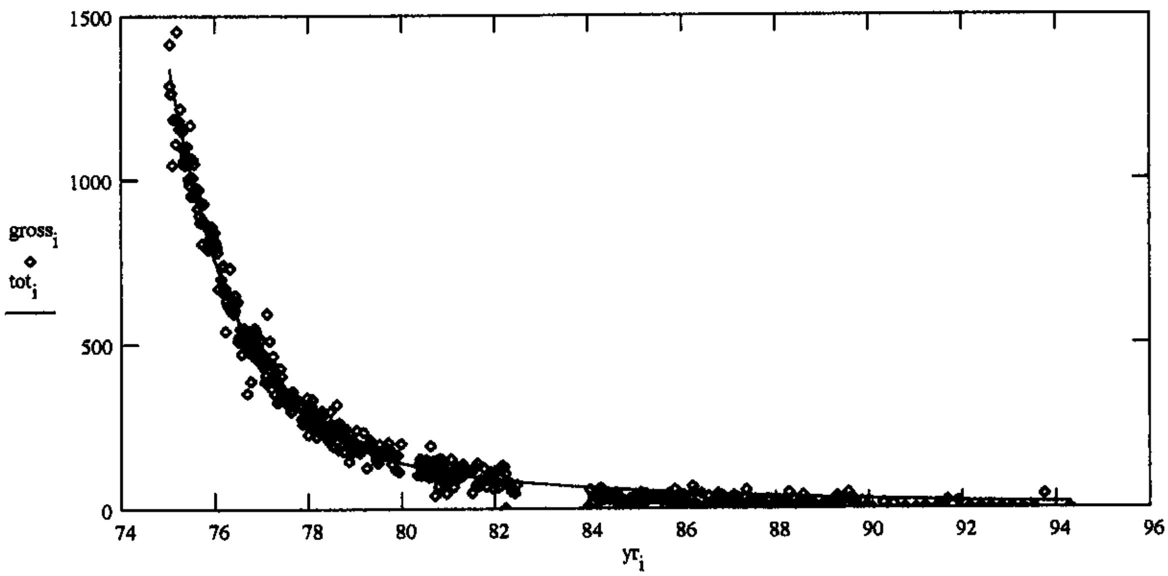
N := last(yr) N = 496 i := 0 .. N k := 0 .. 300 j := 0 .. 299 $\tau eu := 1$

$\tau co := 5.27$ $\tau cs := 3 \cdot 10^9$ aco := 198 acs := 0 Eu variables are Ru-106 aeu := 1174

$Cs_i := acs \cdot e^{-(yr_i - 75) \cdot \frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75) \cdot \frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75) \cdot \frac{\ln(2)}{\tau eu} \cdot 1}$ $tot_i := Co_i + Eu_i$

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75) \cdot \frac{\ln(2)}{\tau co}} + a3 \cdot e^{-(yr_i - 75) \cdot \frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

ssq(aco, aeu) = 0 1 = 1

$\begin{bmatrix} \alpha co \\ \alpha eu \end{bmatrix} := Minerr(aco, aeu)$ $\alpha co = 198$ Co-60 $\alpha eu = 1.174 \cdot 10^3$ Ru-106

$\frac{\alpha co}{\alpha eu} = 0.169$

$Co_i := \alpha co \cdot e^{-(yr_i - 75) \cdot \frac{\ln(2)}{\tau co}}$ $Eu_i := \alpha eu \cdot e^{-(yr_i - 75) \cdot \frac{\ln(2)}{\tau eu}}$ $tot_i := Co_i + Eu_i$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop40-60.txt") := out $\frac{Eu_N}{Co_N} = 1.162 \cdot 10^{-4}$

Dry Well Survey Analysis - Notes

Borehole 22-03-09 Total # Surveys 627 Probe Type 04
neutron surveys 9 # GR Surveys 618
Log Date: 1-16-75 1st 4-20-94 Last Presentation Plot Dates
(If different from 1st & Last)

Contamination Zone Depth(s):
Isotope from Spectral Survey: Cs Co Eu154 Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			Stack for GTP intervals

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Can't do depth shifts due to downward movement
Cs 137 & Ru decay rates are close enough to
look like 1.48 yr T(?) ... over the time span

Analyst Name [signature] S/W ver IFGROSE 2.2

filein := "two00-11.txt" **Well 21-03-09**

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

$\tau eu := 8.5$

N := last(yr) N = 227 i := 0 .. N k := 0 .. 300 j := 0 .. 299

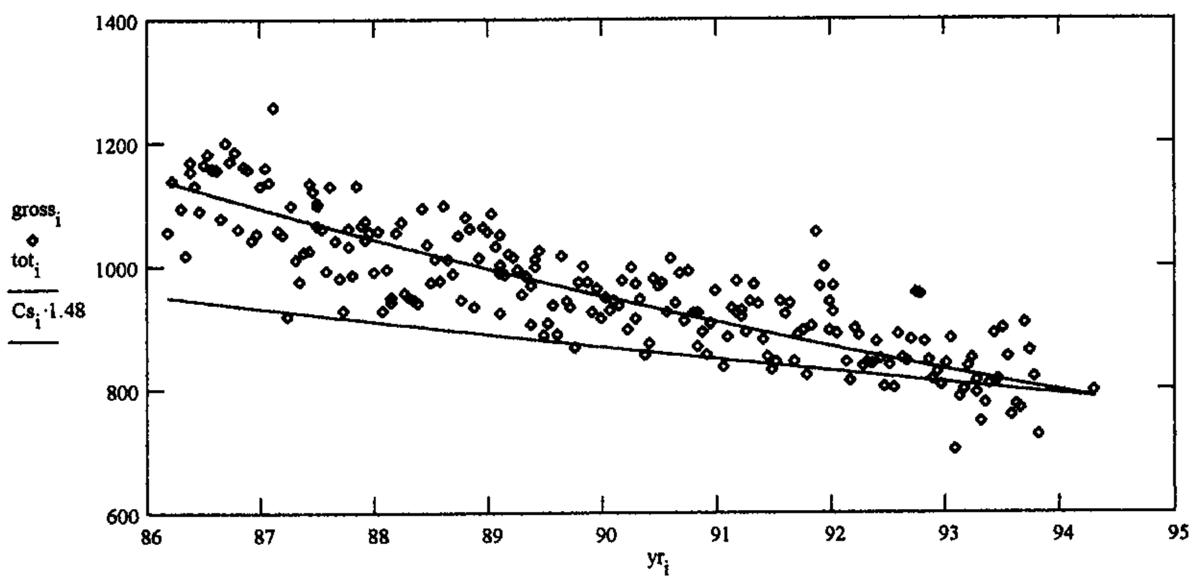
$\tau co := 5.27$ $\tau cs := 30.17$ aco := 00 acs := 830

Eu variables are Ru-106 aeu := 1236

$$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \qquad Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \qquad Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1 \qquad tot_i := Cs_i + Eu_i$$

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

ssq(acs, aeu)=0 1=1

$$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := Minerr(acs, aeu)$$

$\alpha cs = 830.143$ Cs-137 $\alpha eu = 1.237 \cdot 10^3$ Sb-125

$$\frac{\alpha cs}{\alpha eu} = 0.671$$

$$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \qquad Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \qquad tot_i := Cs_i + Eu_i$$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop00-11.txt") := out

$$\frac{Eu_N}{Cs_N} = 0.481$$

filein := "two11-52.txt" **Well 21-03-09**

$A := READPRN(filein)$ $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$ $B := 0$

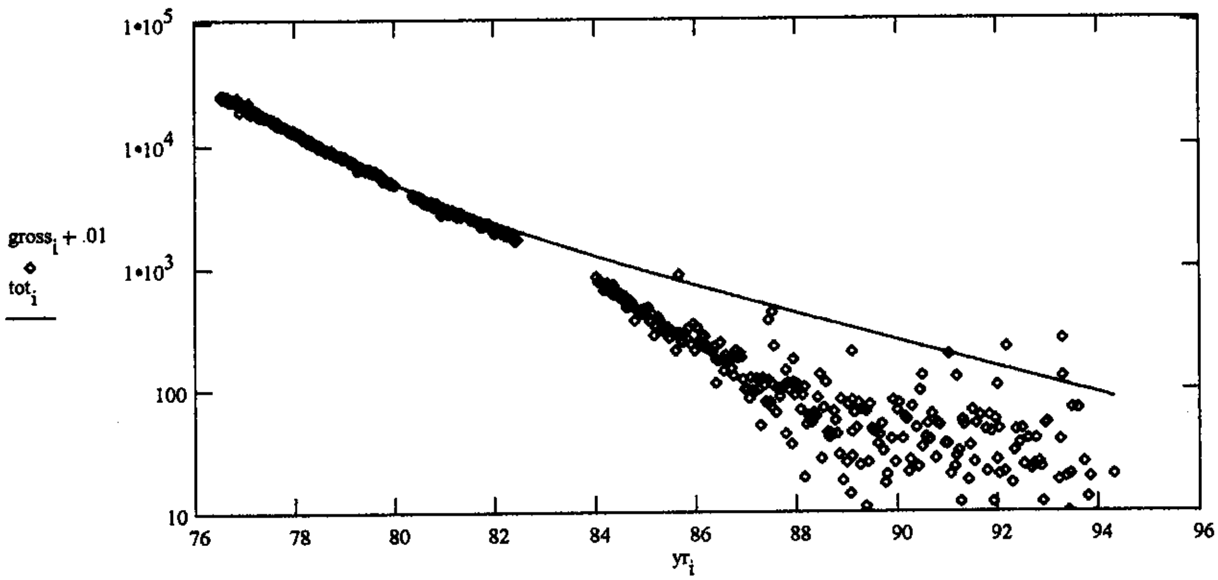
$N := last(yr)$ $N = 528$ $i := 0..N$ $k := 0..300$ $j := 0..299$ $\tau eu := 1$

$\tau co := 5.27 \cdot 10^{9}$ $\tau cs := 2.77$ $aco := 0$ $acs := 10570$ Eu variables are Ru-106 $aeu := 53160$

$Cs_i := acs \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau eu}} \cdot 1$ $tot_i := Cs_i + Eu_i + Co_i + B$

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau eu}} + 0\right]\right]^2$$

Given

$ssq(acs, aeu) = 0$ $1 = 1$ $2 = 2$

$$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := Minerr(acs, aeu)$$

$\alpha cs = 1.057 \cdot 10^{4}$ Sb-125 $\alpha eu = 5.316 \cdot 10^{4}$ Ru-106 Bkg =

$yrf_i := 75 + 20 \cdot \frac{i}{N}$

$\frac{\alpha cs}{\alpha eu} = 0.199$ $\alpha co =$

$Cs_i := \alpha cs \cdot e^{-(yrf_i - 75)\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu \cdot e^{-(yrf_i - 75)\frac{\ln(2)}{\tau eu}}$ $\frac{Bkg}{28} =$

$\frac{Eu_N}{Cs_N} = 7.152 \cdot 10^{-4}$

$tot_i := Cs_i + Eu_i$

$out^{<0>} := yrf$ $out^{<1>} := tot$ WRITEPRN("twop11-52.txt") := out filein := "two24-52B.txt" **Well 21-03-09**

$A := \mathrm{READPRN}(\mathrm{filein})$ $yr := A^{\langle 1\rangle}$ $net := A^{\langle 7\rangle}$ $bkg := A^{\langle 6\rangle}$ $max := A^{\langle 4\rangle}$ $B := 432$

$N := \mathrm{last}(yr)$ $N = 513$ $i := 0..N$ $k := 0..300$ $j := 0..299$ $\tau eu := 1$

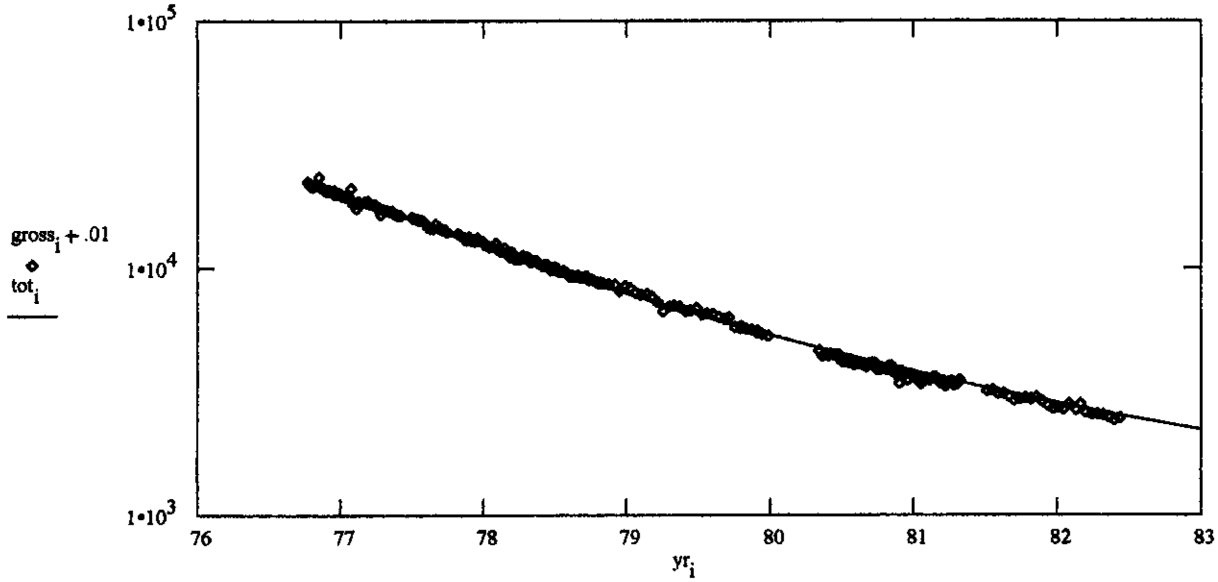
$\tau co := 5.27\cdot 10^{9}$ $\tau cs := 2.77$ $aco := 0$ $acs := 11670$

<u>Eu variables are</u>
<u>Ru-106</u> $aeu := 50890$

$Cs_i := acs\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}\cdot 1$ $tot_i := Cs_i + Eu_i + Co_i + B$

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1, a3, B) := \sum_i \left[gross_i - \left[a1\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} + B\right]\right]^2$$

Given

$ssq(acs, aeu, B) = 0$ $1 = 1$ $2 = 2$

$$\begin{bmatrix}\alpha cs\\ \alpha eu\\ Bkg\end{bmatrix} := \mathrm{Minerr}(acs, aeu, B)$$

$\alpha cs = 1.167\cdot 10^{4}$ $\alpha eu = 5.089\cdot 10^{4}$ $Bkg = 432$

~~Cs-137~~ ~~Sb-125~~
Sb125 Ru106

$yrf_i := 75 + 20\cdot\frac{i}{N}$

$\frac{\alpha cs}{\alpha eu} = 0.229$ $\alpha co =$

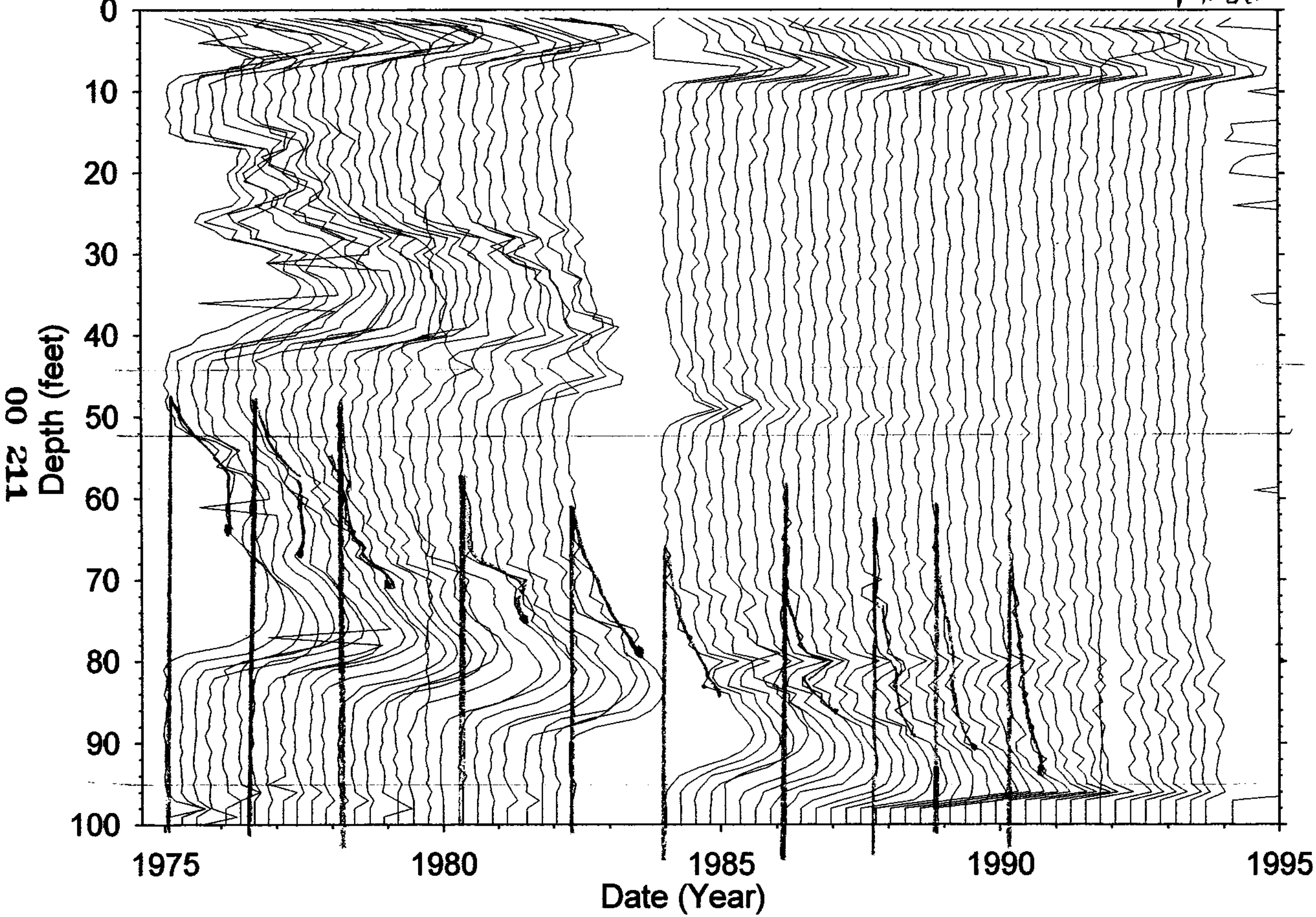
$Cs_i := \alpha cs\cdot e^{-(yrf_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu\cdot e^{-(yrf_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $\frac{Bkg}{28} = 15.429$

$tot_i := Cs_i + Eu_i + Bkg$ $\frac{Eu_N}{Cs_N} = 6.201\cdot 10^{-4}$

$out^{\langle 0\rangle} := yrf$ $out^{\langle 1\rangle} := tot$ WRITEPRN("twop-sb-24-52Bkg.txt") := out

Borehole 22-03-09

USED FOR NOTE PAPER.



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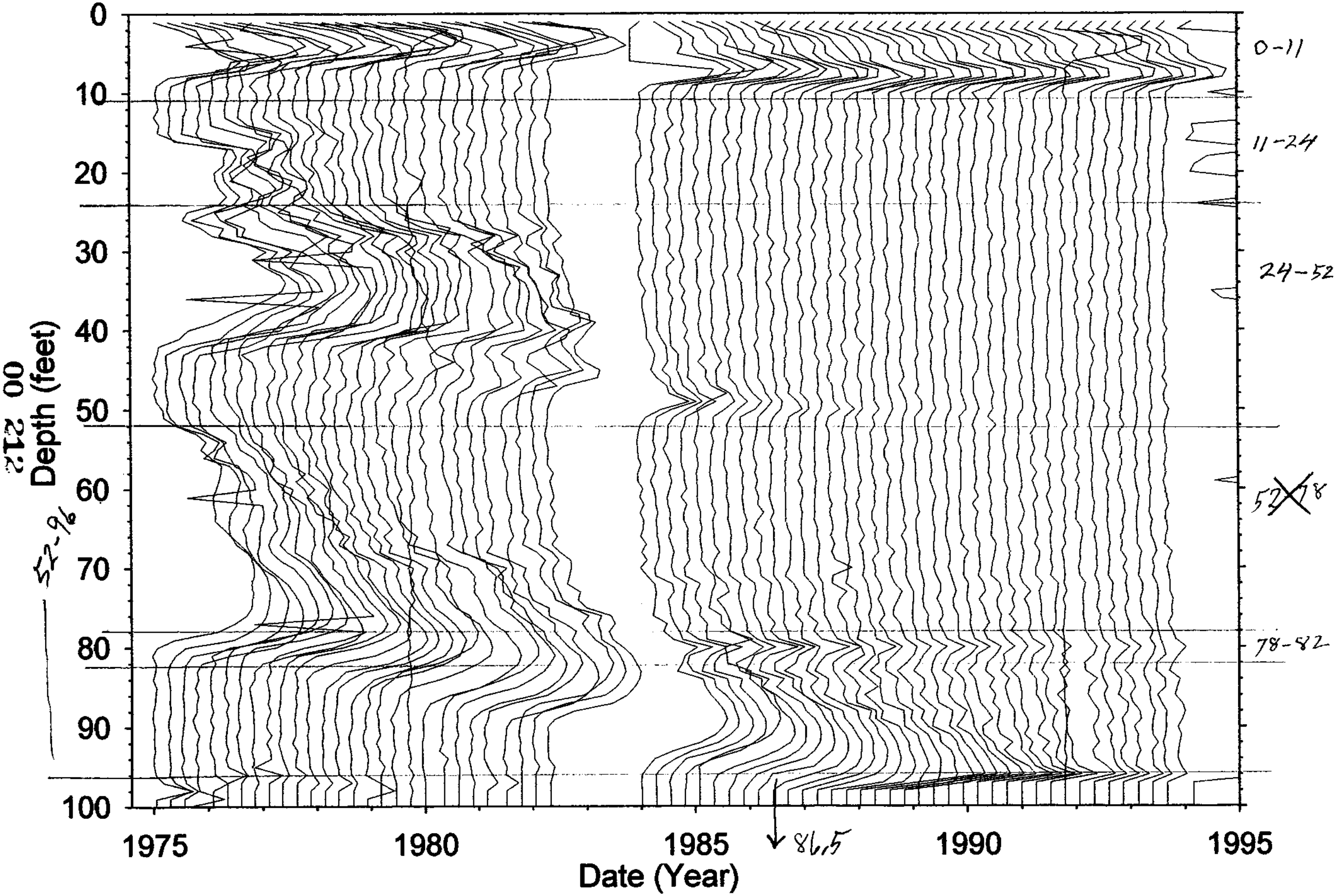
Borehole 22-03-09



BY

Dry Well Survey Analysis - Notes

Borehole 22-03-10 Total # Surveys 479 Probe Type 04

\# neutron surveys 7 # GR Surveys 472

Log Date: 1-16-75 1st 4-20-94 Last Presentation Plot Dates ______

(If different from 1st & Last)

Contamination Zone Depth(s): ______

Isotope from Spectral Survey: Cs low Max Survey Depth 90

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment
			Some time after '80 100' → 85'

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			Surf & 10-30+ long lived

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

0-8 8-30

Analyst Name Russ Randall S/W ver TFGROSS 2.2

Borehole 22-04-01

Contamination (Ru-106) from 20-35 feet is Stable
Contamination (Ru-106) from 35-45 feet is Stable

Grade thickness product over 20 to 35 feet is decreasing consistent with Ru-106 (hypothesis) decay. There may be some indication of non-stability from 1981 through 1987, but the levels are near threshold and no definite conclusion can be reached.

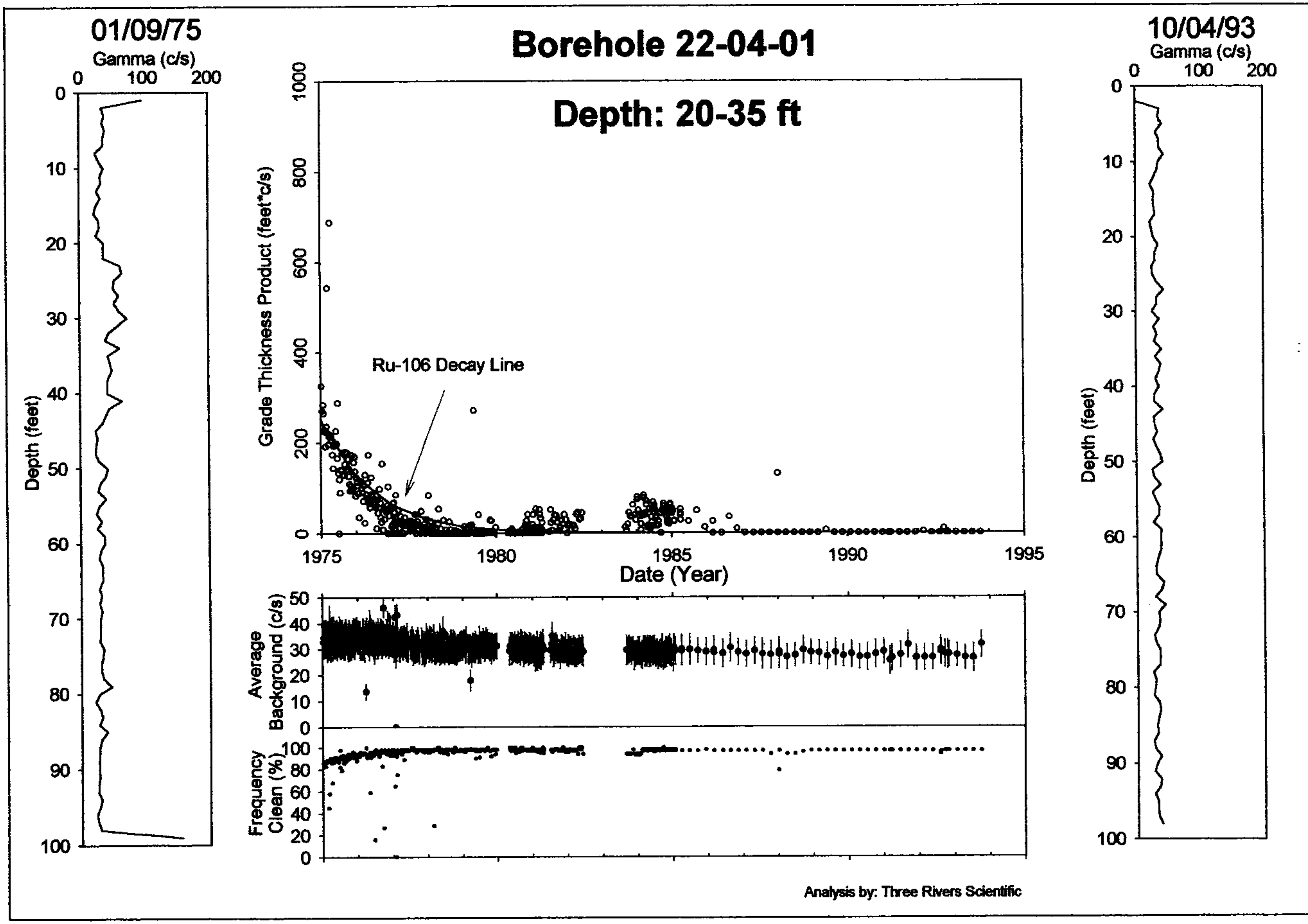
Grade thickness product over 35 to 45 feet is decreasing consistent with Ru-106 (hypothesis) decay.

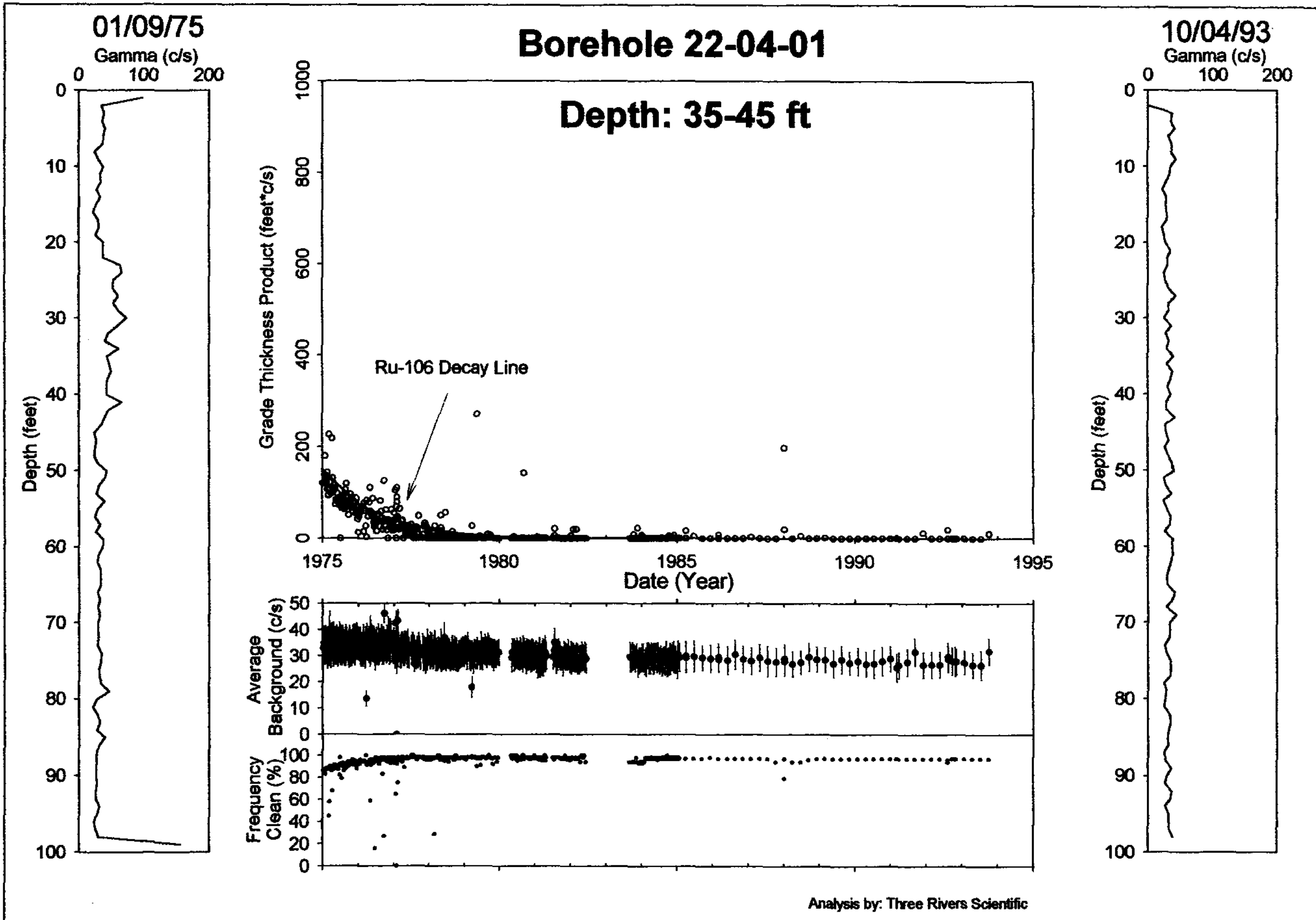
Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/9/1975
Last Survey Date :	10/4/1993
Number Surveys :	439

Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50 for 20-35 & 35-45 Threshold 0<val<40 for 20-45	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	20-35 & 35-45 Stable	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	


Borehole 22-04-01
Depth: 20-35 ft
01/09/75
Gamma (c/s)
Depth (feet)
10/04/93
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Ru-106 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific



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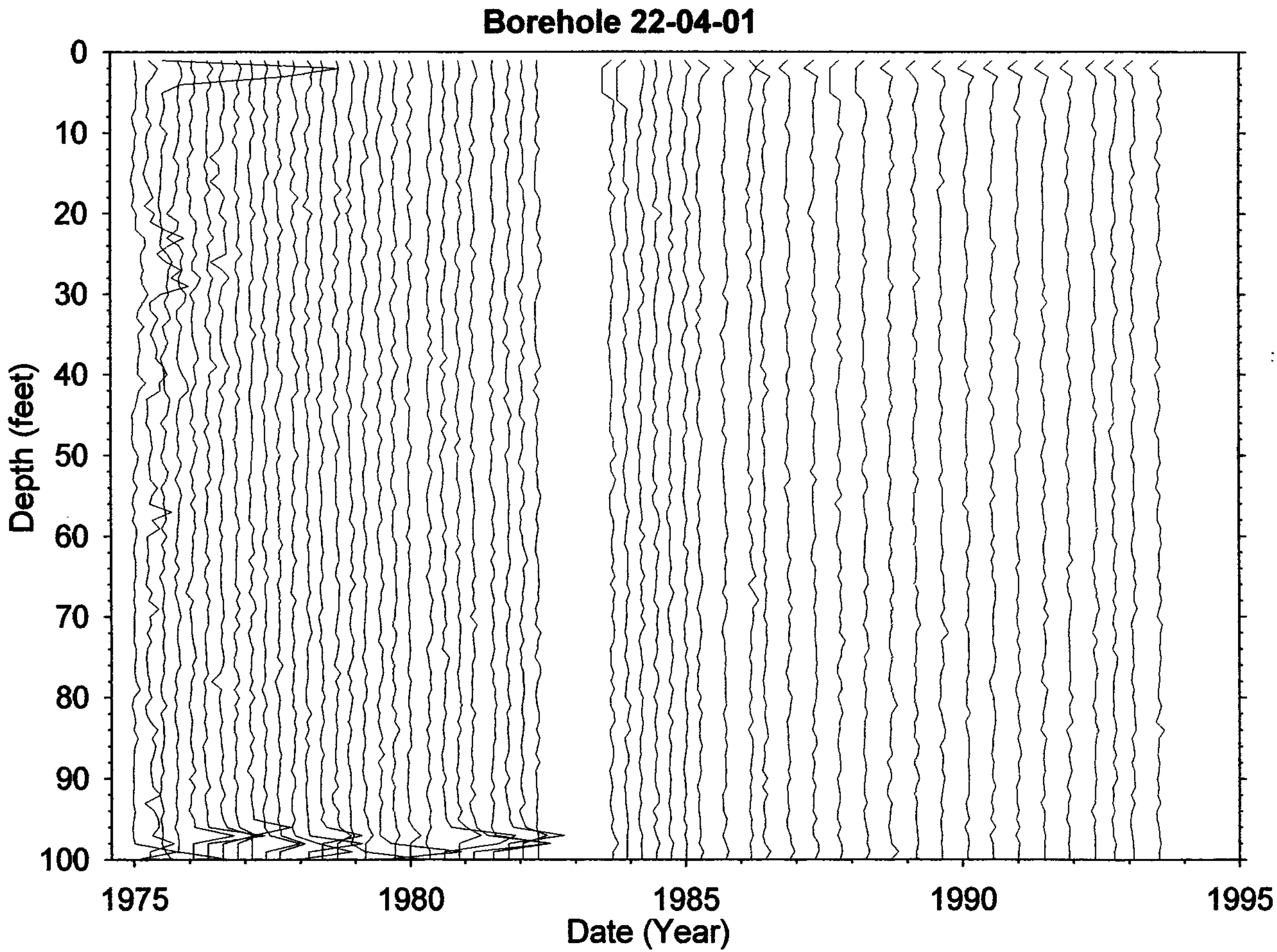
00 216



HNF-3532 -REV0

00 217

Borehole 22-04-05

No Gamma Ray Emitting Contamination was identified.

No significant levels of gamma ray contamination are present above the survey probe detection threshold between 1975 and 1993 in the vadose zone from 2 to 100 feet.

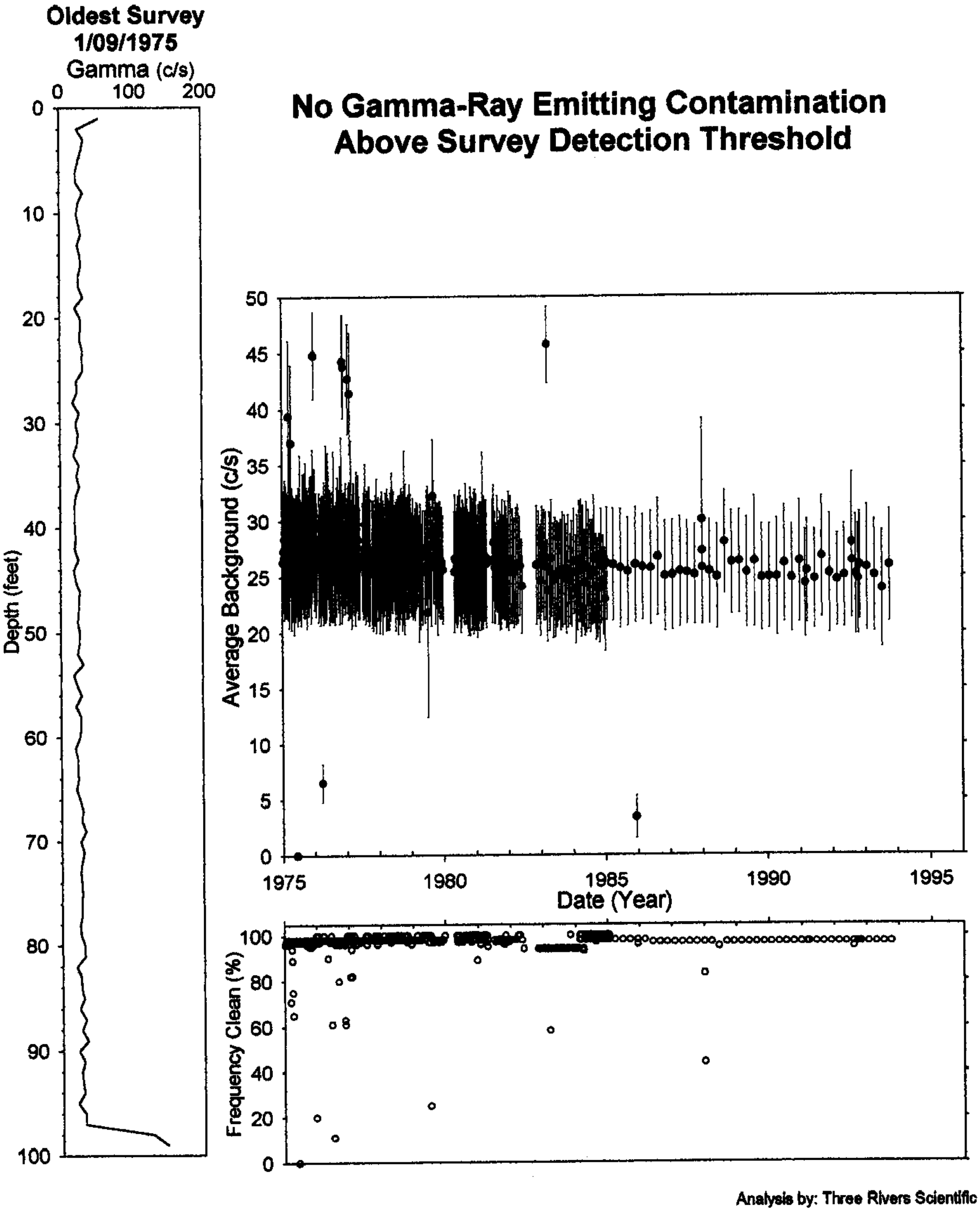
Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/9/1975
Last Survey Date :	10/4/1993
Number Surveys :	403

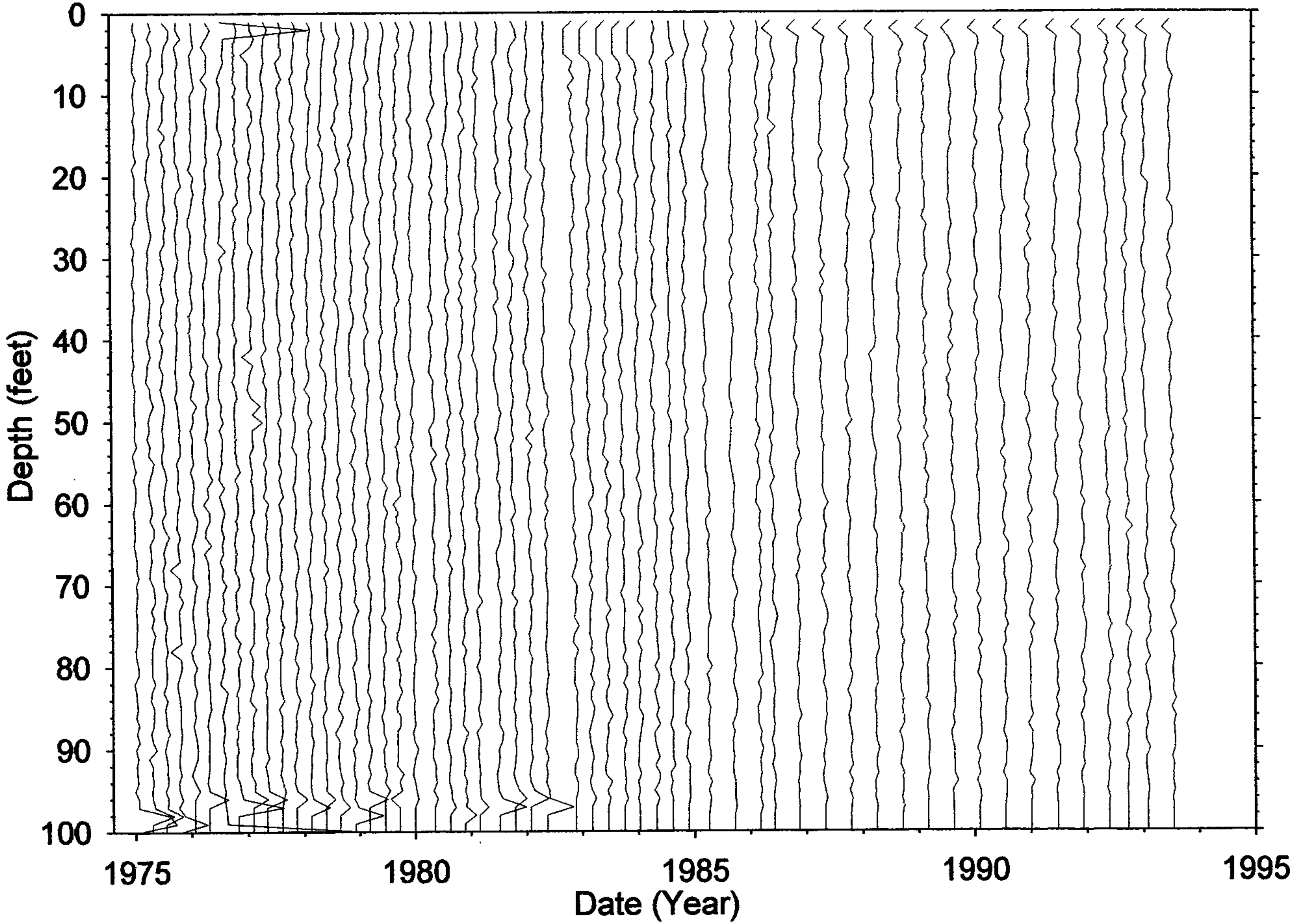
Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	

Borehole 22-04-05



Borehole 22-04-05



HNF-3532 -REV0

Borehole 22-04-07

No Gamma Ray Emitting Contamination was identified.

No significant levels of gamma ray contamination are present above the survey probe detection threshold between 1975 and 1993 in the vadose zone from 2 to 100 feet.

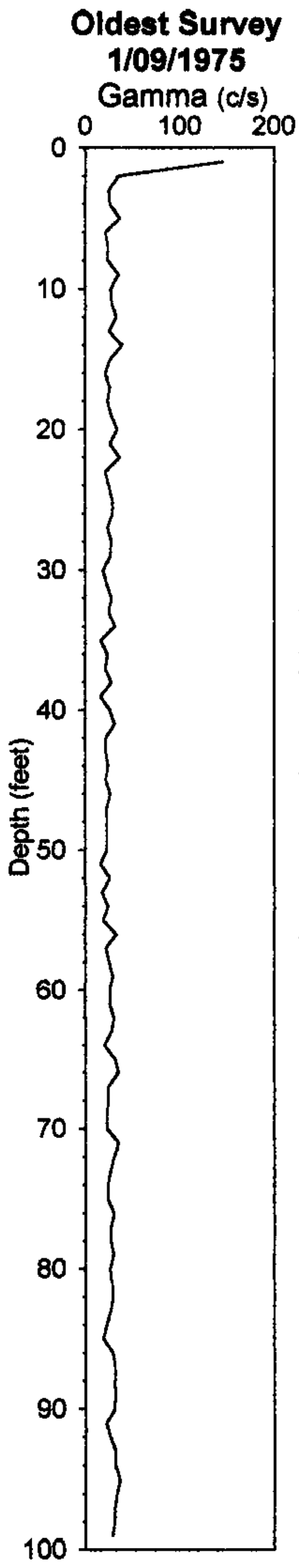
Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/9/1975
Last Survey Date :	10/4/1993
Number Surveys :	409

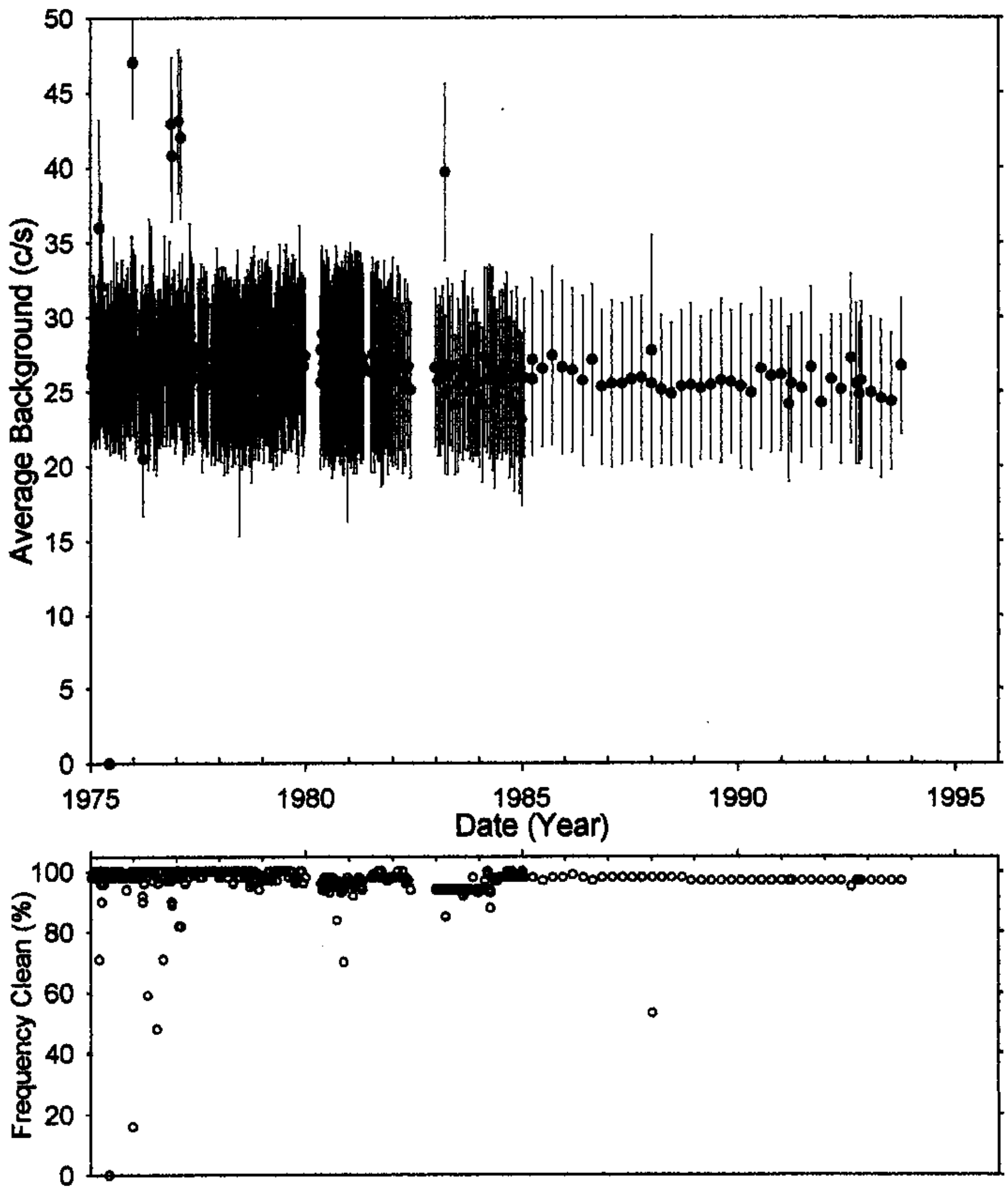
Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	

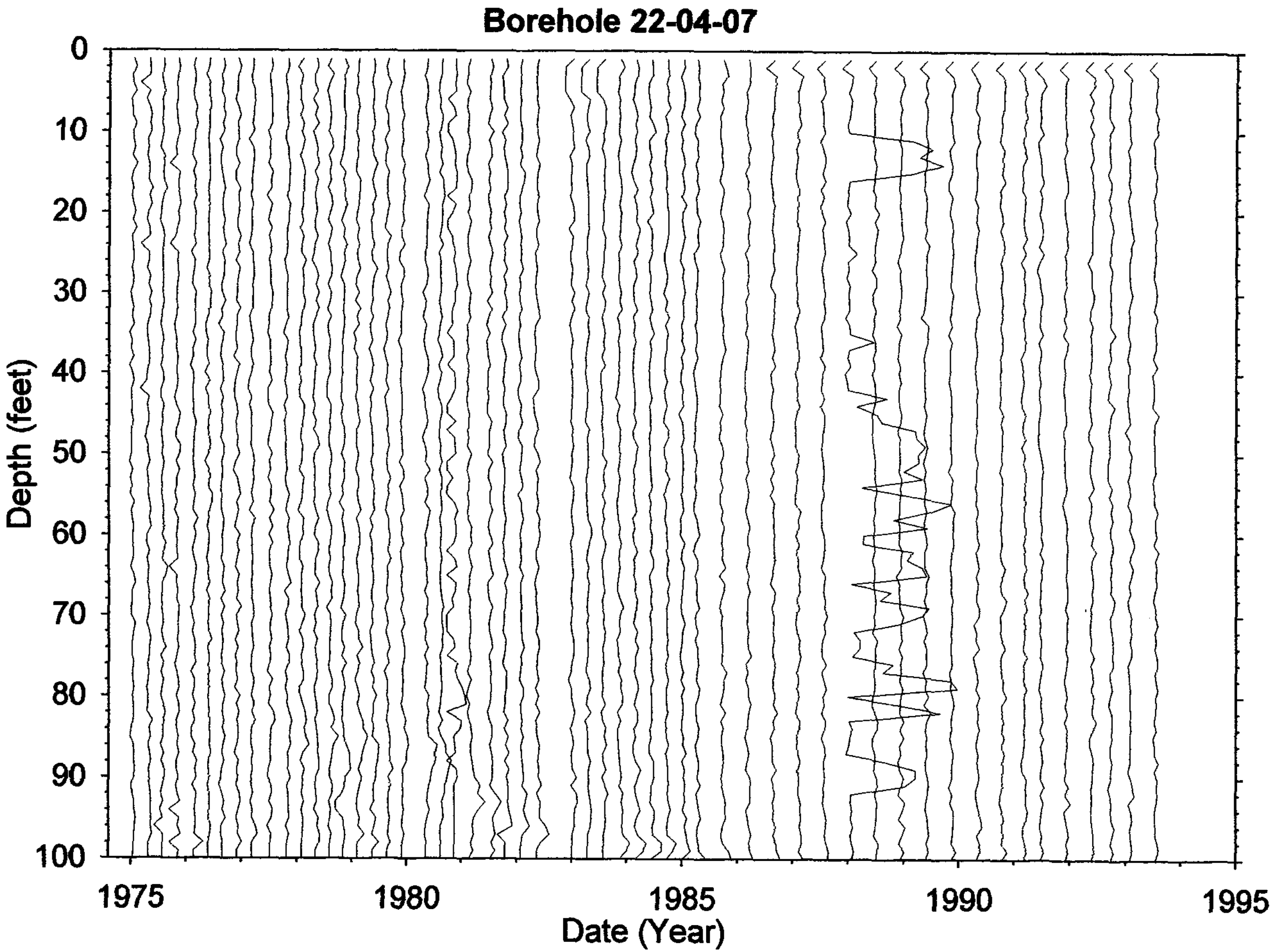
Borehole 22-04-07



No Gamma-Ray Emitting Contamination Above Survey Detection Threshold



Analysis by: Three Rivers Scientific


Borehole 22-04-07
0
10
20
30
40
50
60
70
80
90
100
Depth (feet)
1975
1980
1985
1990
1995
Date (Year)

Borehole 22-04-09

Contamination (Cs-137) from 0-8 feet is Tank Farm Activity
Contamination (Co-60) from 75-95 feet is **UNSTABLE** Early
Contamination (Co-60) from 105-120 feet Stable (when logged)

Grade thickness product, Cs-137 (HPGe identified), from 0 to 8 feet is erratic, indicative of tank farm activities such as transfer line operations. The grade thickness product for this interval appears stable from 1986 to 1993.

Grade thickness product over 75 to 95 feet is increasing starting mid 1979. After the rapid increase stops in mid 1980 until1982 the grade thickness product is not changing consistent with Co-60 (HPGe identified) from mid 1979 to 1982. A rapid decrease indicated by four surveys in early 1982 ends with a data gap, and when logging data resumes, the decay appears consistent with Co-60, but at low levels.

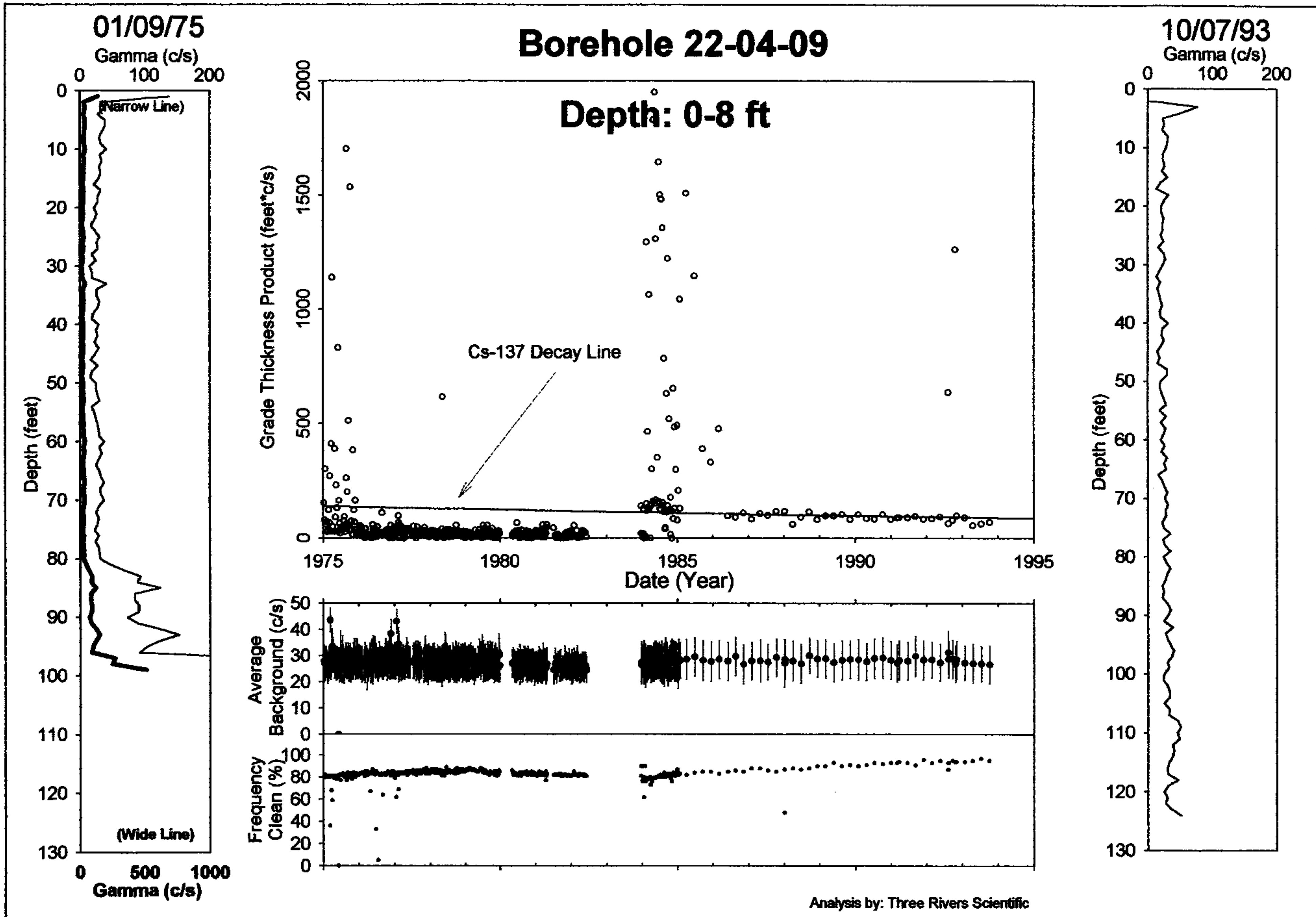
Grade thickness product, Co-60 (HPGe identified) from 105 to 120 feet first appears 12-22-83 due to apparent well deepening and from this time to 1993 is stable. Special note that there are no data to indicate downward movement if it occurred; however, the contaminant could be in this interval (105-120 feet) as a result of the drilling process.

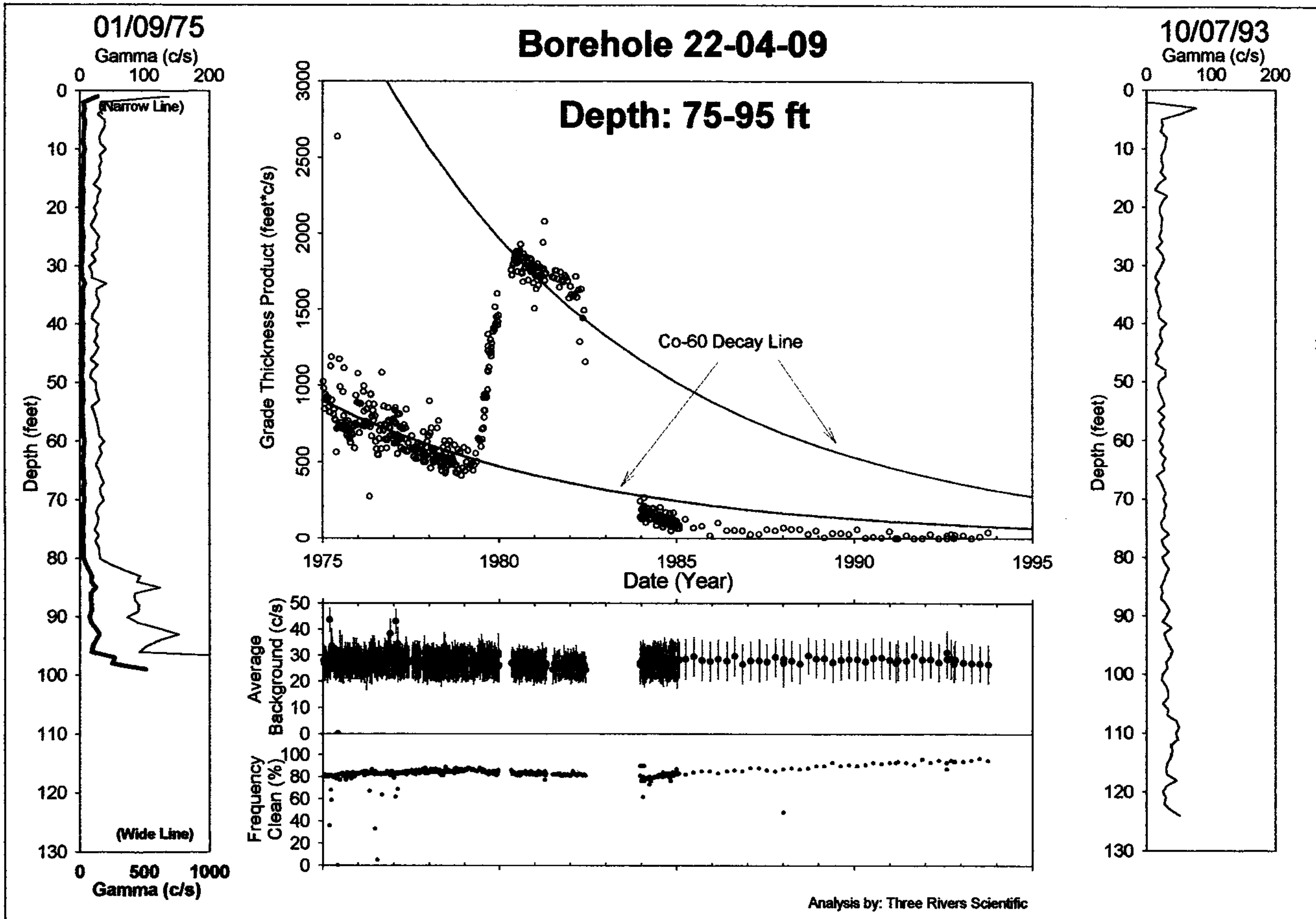
Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	125 ft present
Survey Depth :	100 ft at start and 125 ft after 12-22-83
First Survey Date :	1/9/1975
Last Survey Date :	10/7/1993
Number Surveys :	451

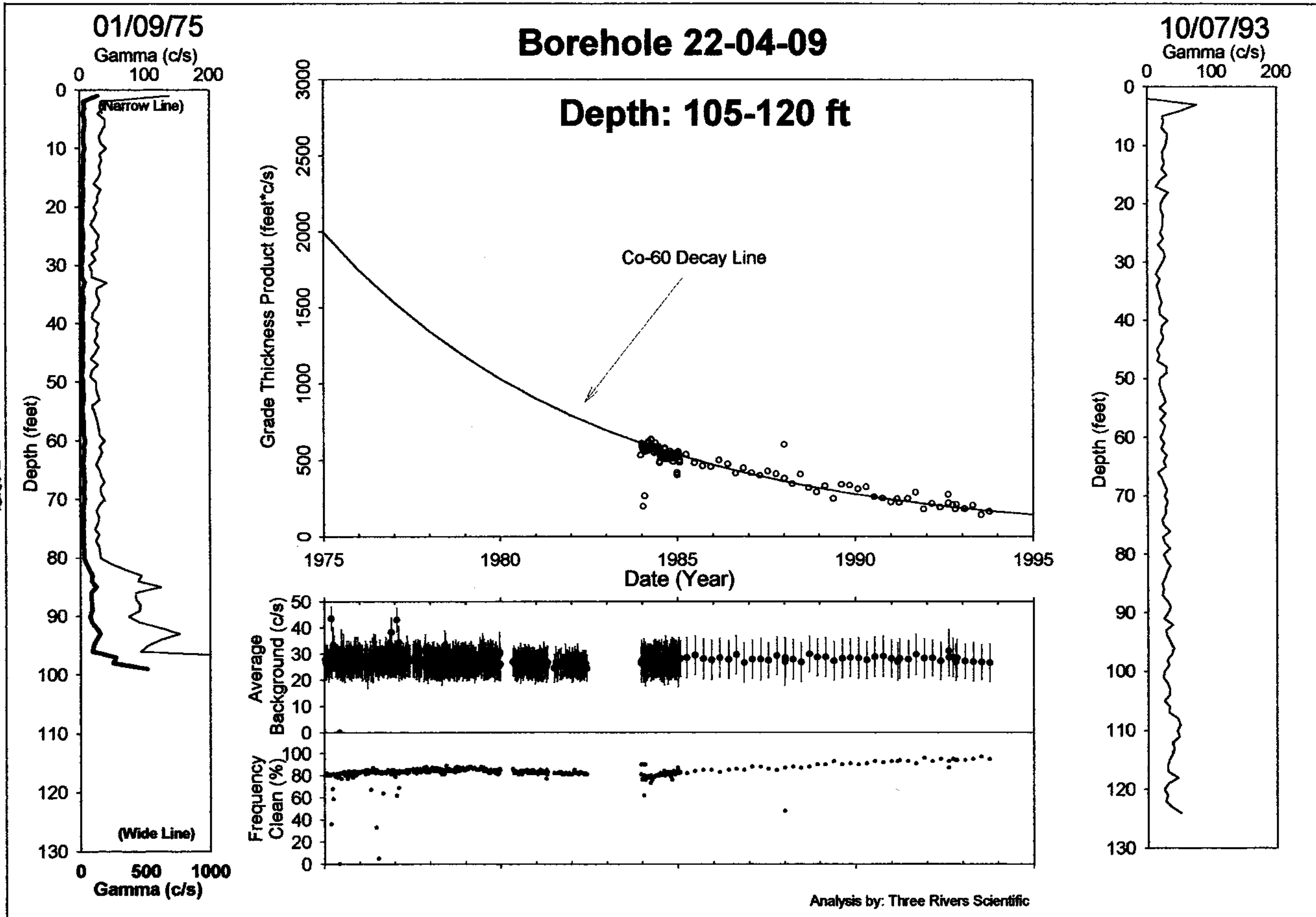
Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-8 Tank Farm Activity, 75-95 **UNSTABLE**, 105-120 Stable (when logged)	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	


01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Gamma (c/s)
Depth (feet)
Borehole 22-04-09
Depth: 0-8 ft
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
10/07/93
Gamma (c/s)
Depth (feet)

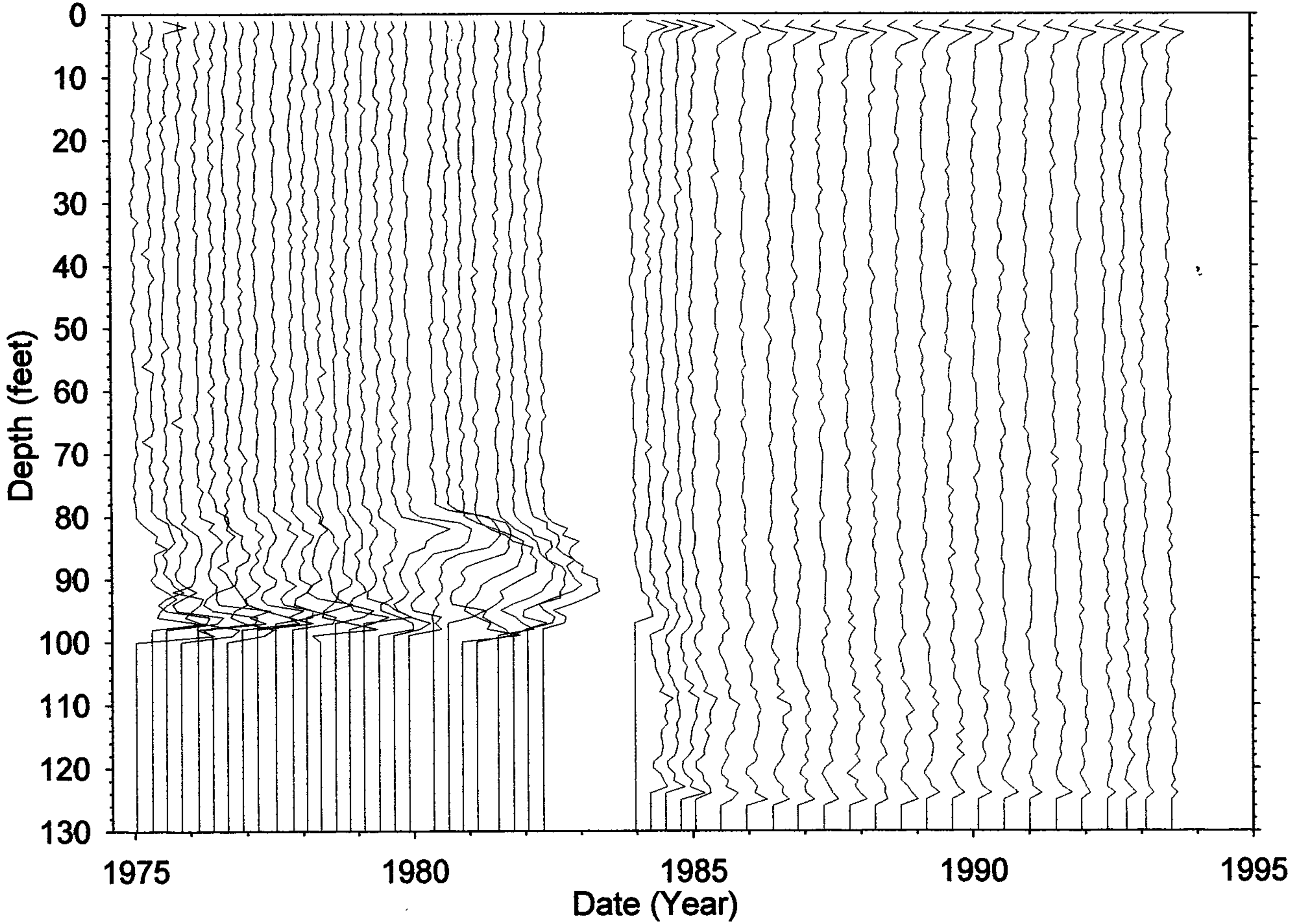


Borehole 22-04-09
Depth: 75-95 ft
01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
10/07/93
Analysis by: Three Rivers Scientific


01/09/75
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100 110 120 130
(Wide Line)
0 500 1000
Gamma (c/s)
Borehole 22-04-09
Depth: 105-120 ft
Grade Thickness Product (feet*c/s)
0 500 1000 1500 2000 2500 3000
Co-60 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
10/07/93
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100 110 120 130

00 227

Borehole 22-04-09



HNF-3532 -REV0

Borehole 22-04-11

Contamination (Cs-137) from 0-8 feet is Tank Farm Activity
Contamination (Cs-137) from 10-25 feet is Stable
Contamination (Ru-106) from 25-50 feet is Stable
Contamination (Co-60) from 90-100 feet is Undetermined

Grade thickness product, Cs-137 (HPGe identified), from 0 to 8 feet is erratic, indicative of tank farm activities such as transfer line operations. The grade thickness product appears stable from 1986 to 1994.

Grade thickness product from 10 to 25 feet is decreasing consistent with Cs-137 (HPGe identified) from 1975 to 1994.

Grade thickness product from 25 to 50 feet is decreasing nearly consistent with Ru-106 (hypothesis) from 1975 to 1994. Special note, there is a very slight deviation early from a single Ru-106 decay. The addition of a longer lived component cannot be computed since the levels of confidence do not allow such a procedure and a definitive statement.

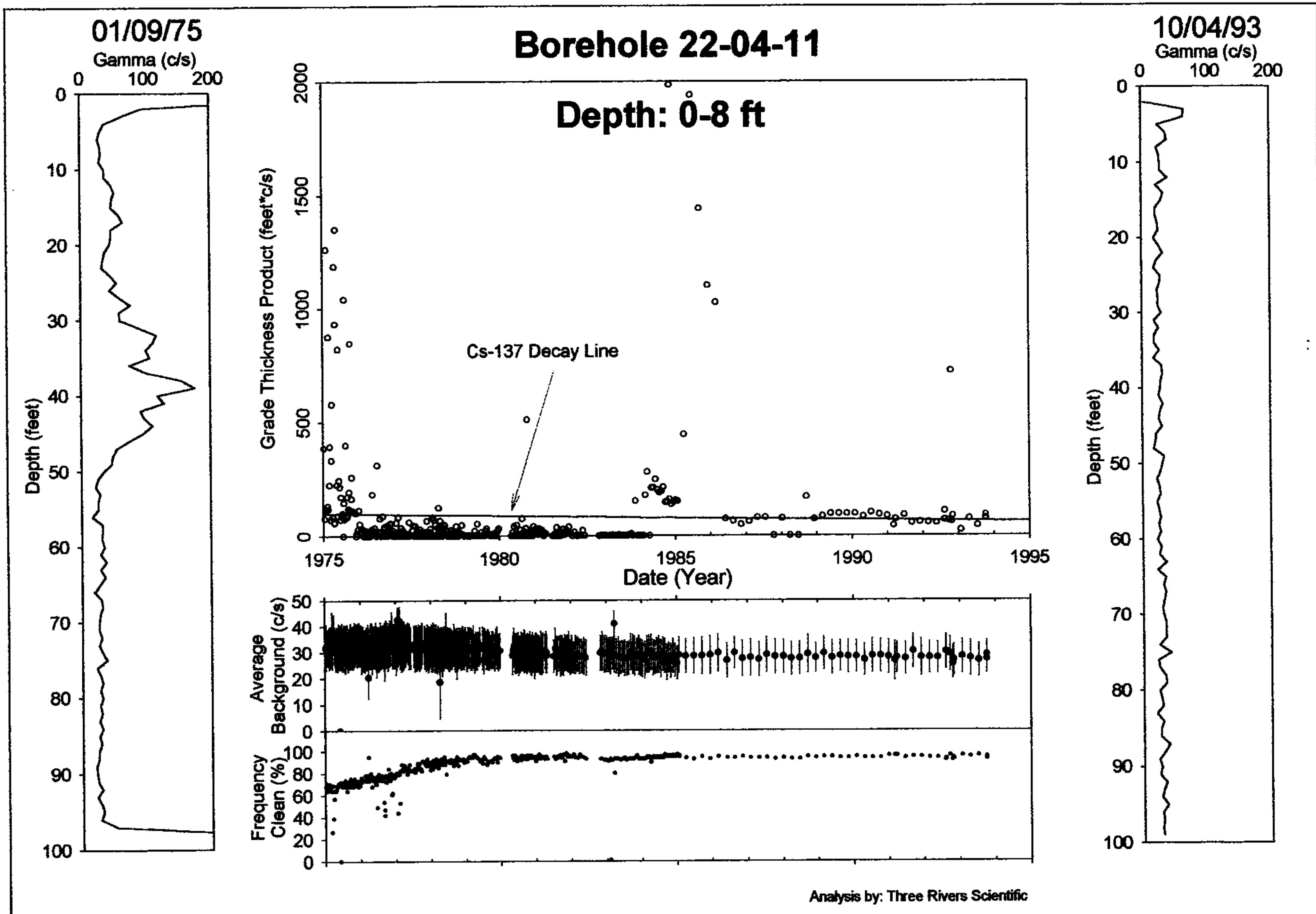
Grade thickness product from 90 to 100 feet is decreasing consistent with Co-60 (HPGe identified), between 1976 and mid 1982, but gross gamma logging was not designed to accurately measure near the surface or bottom of the borehole. Also, some presence of a rapid decay is indicated from1975 to 1976, but system limitations do no allow a conclusion.

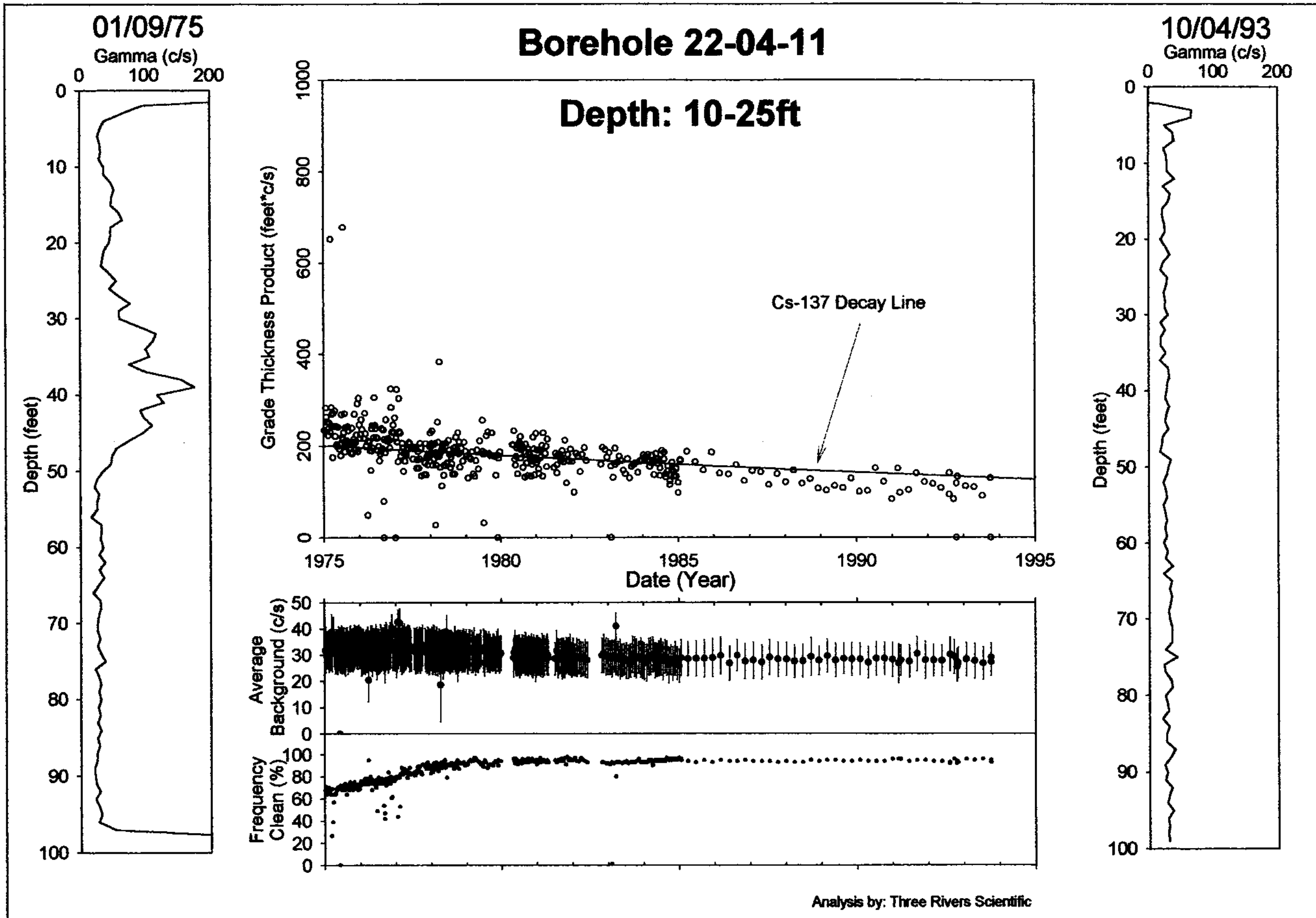
Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	14: Shielded NaI, 02: Red GM, 03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/15/1975
Last Survey Date :	10/4/1993
Number Surveys :	405

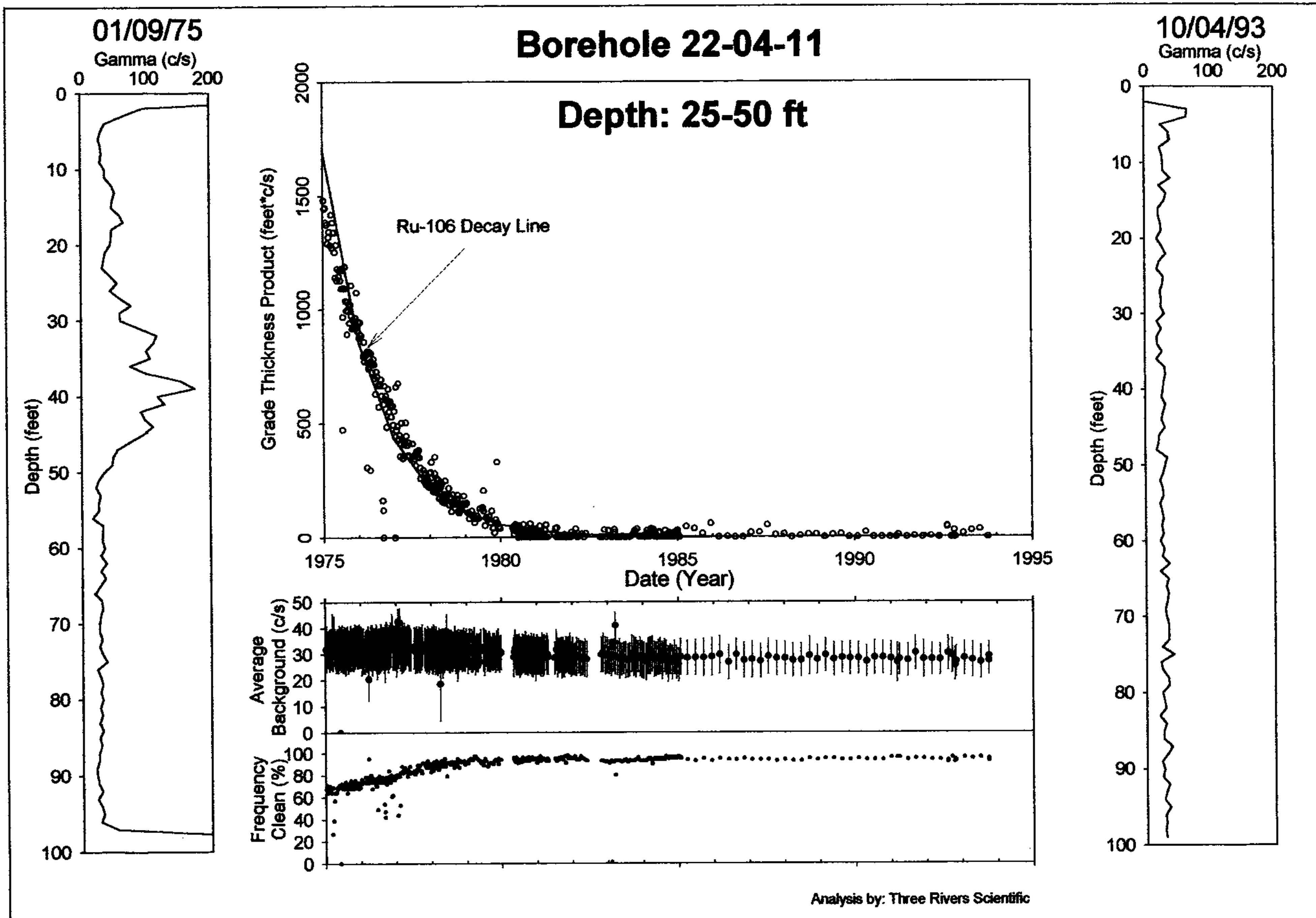
Analysis Notes

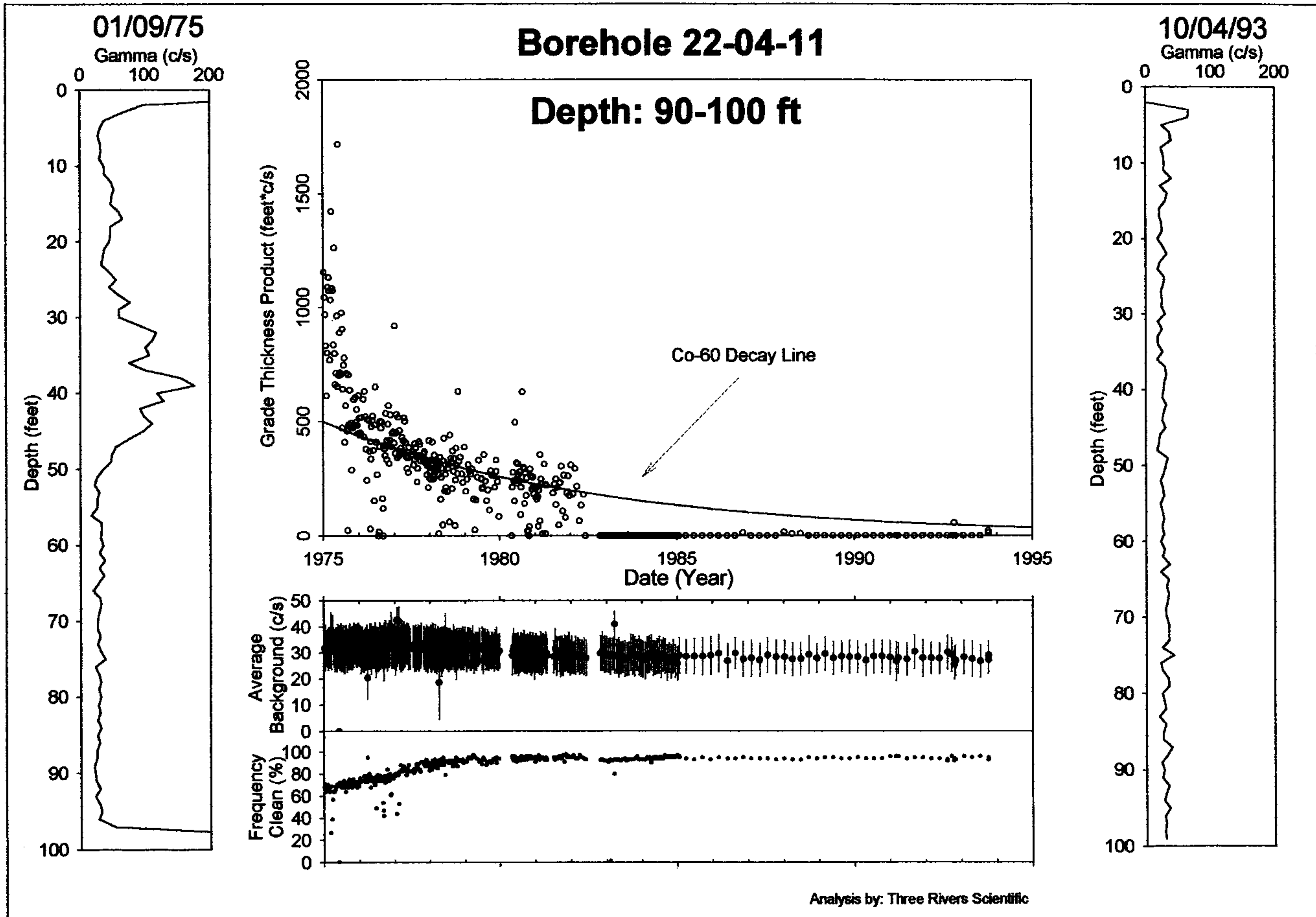
Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-8 Tank Farm Activity 10-25 & 25-50 Stable 90-100 Undetermined	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	


Borehole 22-04-11
Depth: 0-8 ft
01/09/75
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
10/04/93
Analysis by: Three Rivers Scientific



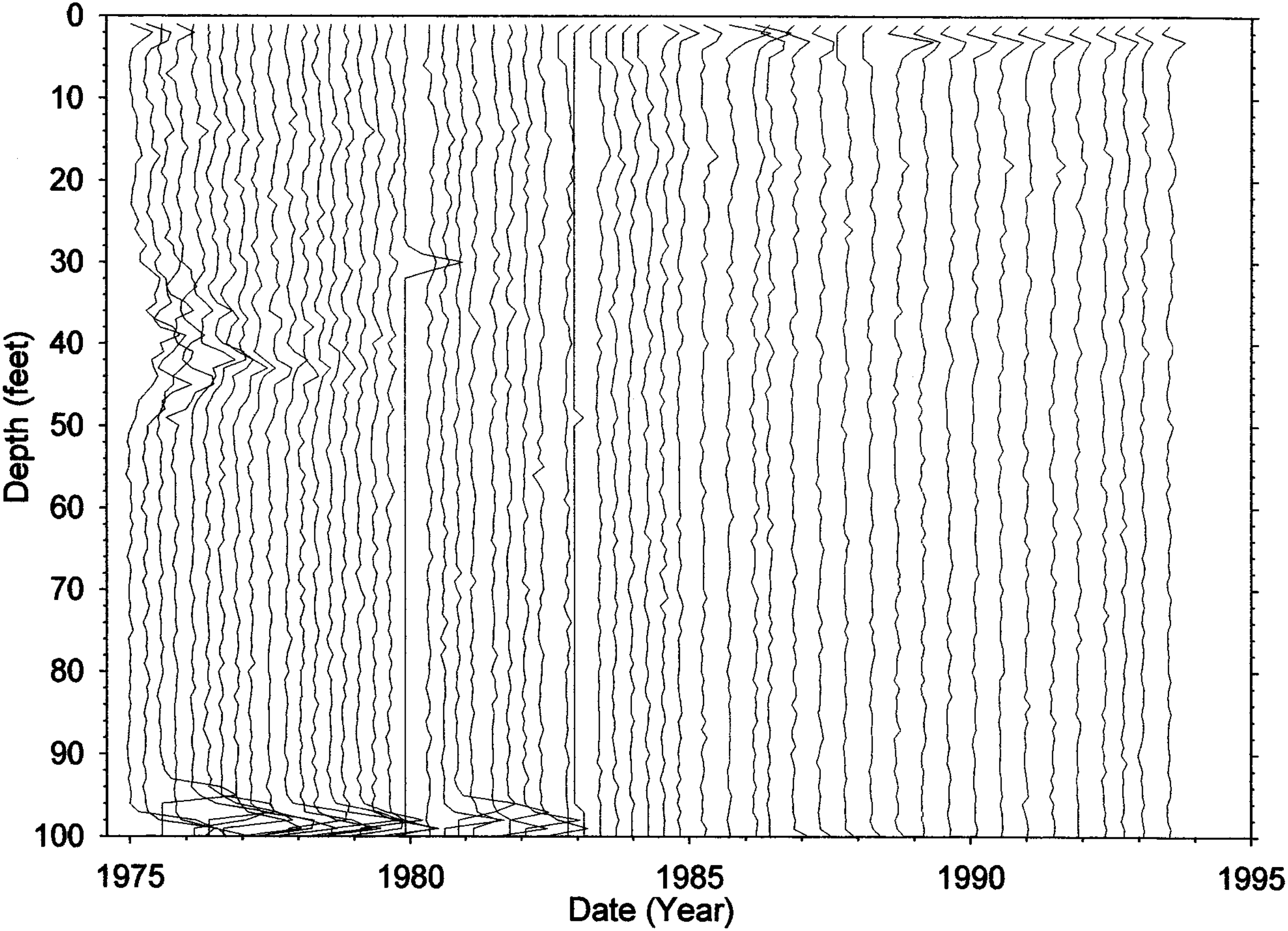
Borehole 22-04-11
Depth: 10-25ft
01/09/75
Gamma (c/s)
Depth (feet)
10/04/93
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific


01/09/75
Gamma (c/s)
Depth (feet)
Borehole 22-04-11
Depth: 25-50 ft
Grade Thickness Product (feet*c/s)
Ru-106 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
10/04/93
Gamma (c/s)
Depth (feet)


Borehole 22-04-11
Depth: 90-100 ft
01/09/75
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
10/04/93
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific

00 233

Borehole 22-04-11



HNF-3532 -REV0

BY

Dry Well Survey Analysis - Notes

Borehole 22-04-01
Total # Surveys 441
Probe Type 04
neutron surveys 2
GR Surveys 439
Log Date: 1-9-75 1st
10-4-93 Last
Presentation Plot Dates ________
(If different from 1st & Last)

Contamination Zone Depth(s): ________
Isotope from Spectral Survey: Co Some levels all depths
Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			Two zones early 20-35 4 @ 40
			gone by 77

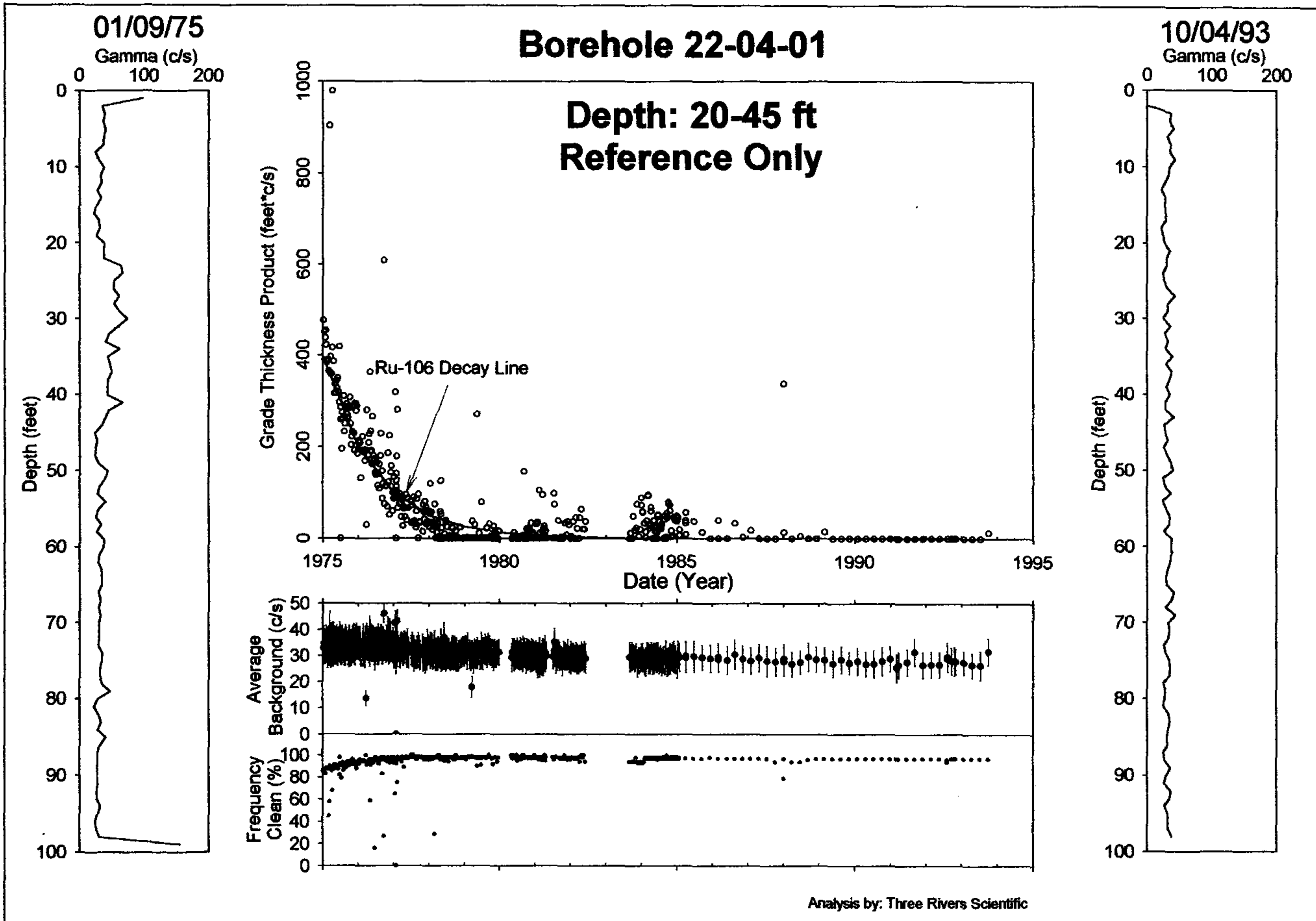
BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

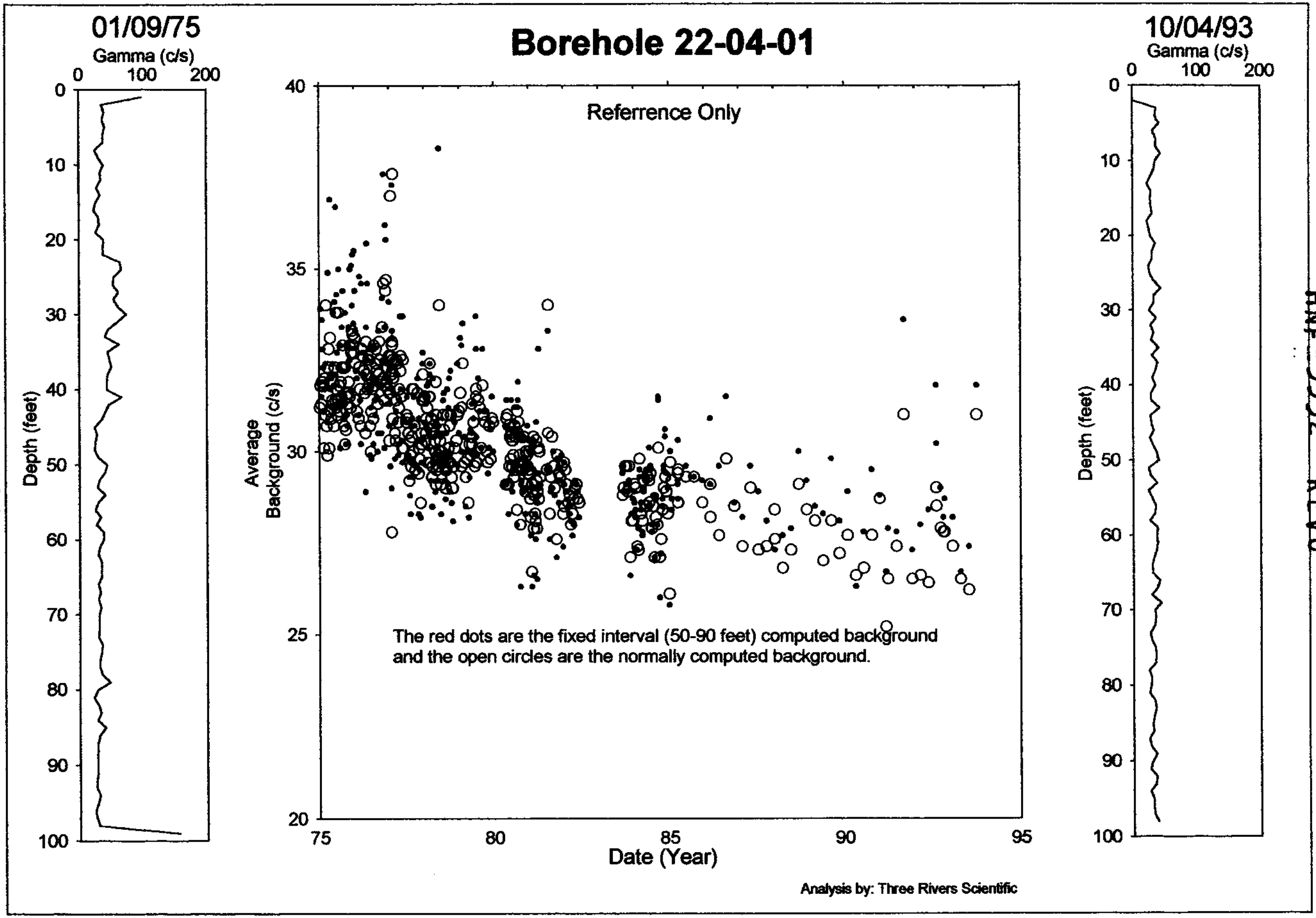
Analysis Notes

20-45 used 0-40 threshold bkg
Also checked bkg change & not due to Ru
interference see organdance plot.

Analyst Name Bruce Randall
S/W ver TTGROSS 2.2



HNF-3532 -REV0



Borehole 22-04-01
01/09/75
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
10/04/93
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
Referrence Only
Average Background (c/s)
20 25 30 35 40
Date (Year)
75 80 85 90 95
The red dots are the fixed interval (50-90 feet) computed background and the open circles are the normally computed background.
Analysis by: Three Rivers Scientific

BY

Dry Well Survey Analysis - Notes

Borehole 22-04-05 Total # Surveys 405 Probe Type 04
neutron surveys 2 # GR Surveys 403
Log Date: 1-9-75 1st 10-4-93 Last Presentation Plot Dates ____
(If different from 1st & Last)

Contamination Zone Depth(s): Clean
Isotope from Spectral Survey: Cs shallow & low levels Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			Intermittant near surface
			Stack → clean

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

1st Clean well in this farm

Analyst Name [signature] S/W ver TFGR0552.2

Dry Well Survey Analysis - Notes

Borehole 22-04-07 Total # Surveys 411 Probe Type 04

\# neutron surveys 2 # GR Surveys 409

Log Date: 1-9-75 1st 10-4-93 Last Presentation Plot Dates ______

(If different from 1st & Last)

Contamination Zone Depth(s): ______

Isotope from Spectral Survey: Cs [illegible] surf Co deep & low level Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			84-86 every other has surface hit
			Clean - Co does not show

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Analyst Name [signature] S/W ver TF6R0SS 2.2

Dry Well Survey Analysis - Notes

BY

Borehole 22-04-09 Total # Surveys 456 Probe Type 04

\# neutron surveys 5 # GR Surveys 451

Log Date: 1-9-75 1st 10-7-93 Last Presentation Plot Dates ____
(If different from 1st & Last)

Contamination Zone Depth(s): ____

Isotope from Spectral Survey: Cs low & awf Co deep & low Max Survey Depth 128

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			75-95', looks like well deepened start '84.
			also 105-120
			deepened between 6-8-82 & 12-22-83

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

75-95
105-120
0-8 TF activity but stable late

Analyst Name Ross Randall S/W ver TFGROSS 2.2

BY

Dry Well Survey Analysis - Notes

Borehole 22-04-11 Total # Surveys 407 Probe Type 04

\# neutron surveys 2 # GR Surveys 405

Log Date: 1-9-75 1st 10-4-93 Last Presentation Plot Dates ____ (If different from 1st & Last)

Contamination Zone Depth(s): ____

Isotope from Spectral Survey: Cs low shallow Co very low deep Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			a quick decay @ 40' ± 10'
			surface 0-8' & bottom 95-100 ±77
			& a long lived peak @ 18'

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

From Stack	0-8	10-25	25-50	40-100

Analyst Name Russ Randall S/W ver TFGROSS 2.2

Borehole 22-05-01

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity

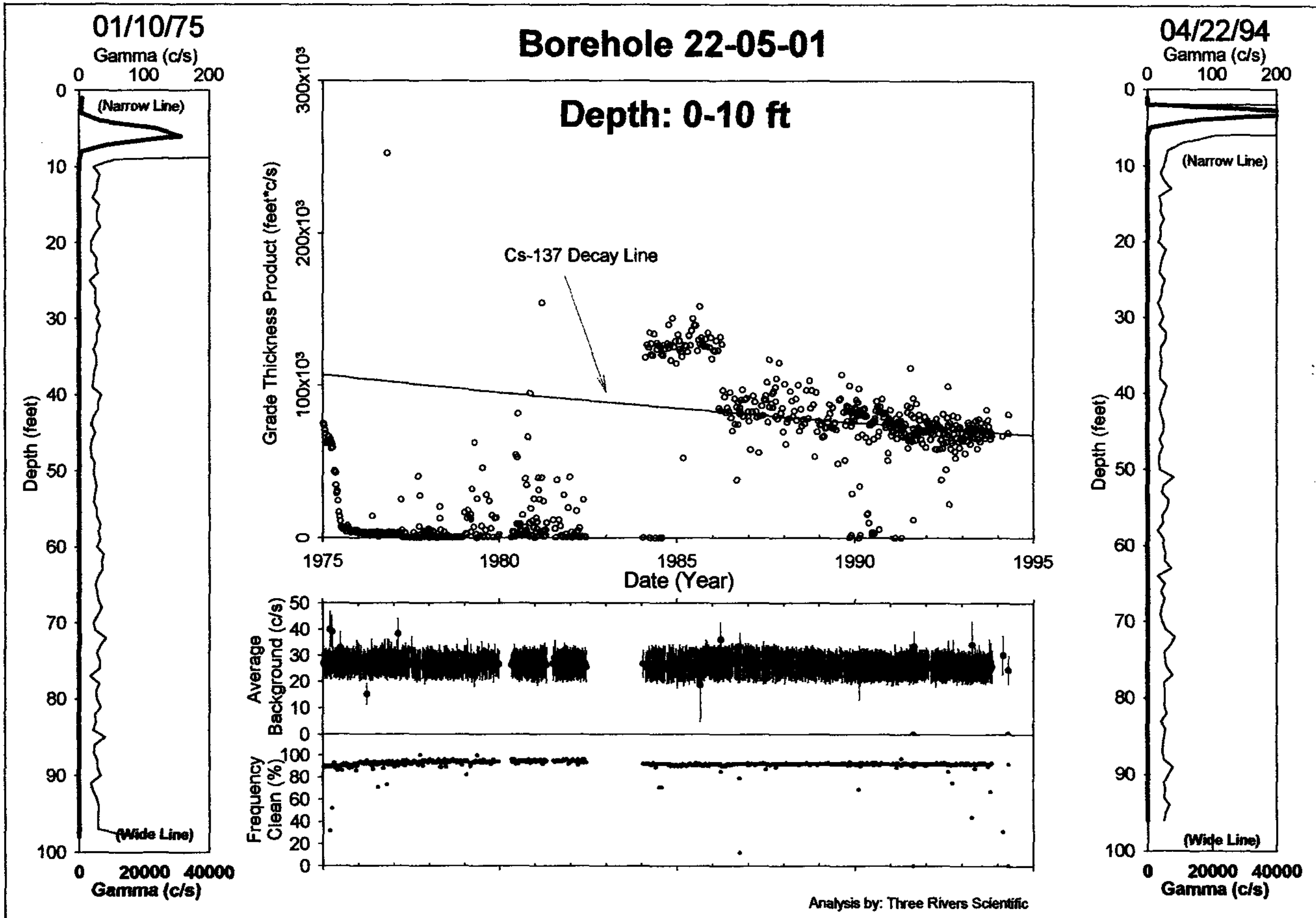
Grade thickness product Cs-137 (HPGe identified) from 0 to 10 feet is erratic indicative of tank farm activities such as transfer line operations. However, some of the surveys are near the limits of count rate at 20,000 to 40,000 c/s. Also, the consistent steady decline from Jan 10, 1975 to Jul 11, 1975 is not usual for such "Tank Farm Activity".

Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/10/1975
Last Survey Date :	4/22/1994
Number Surveys :	737

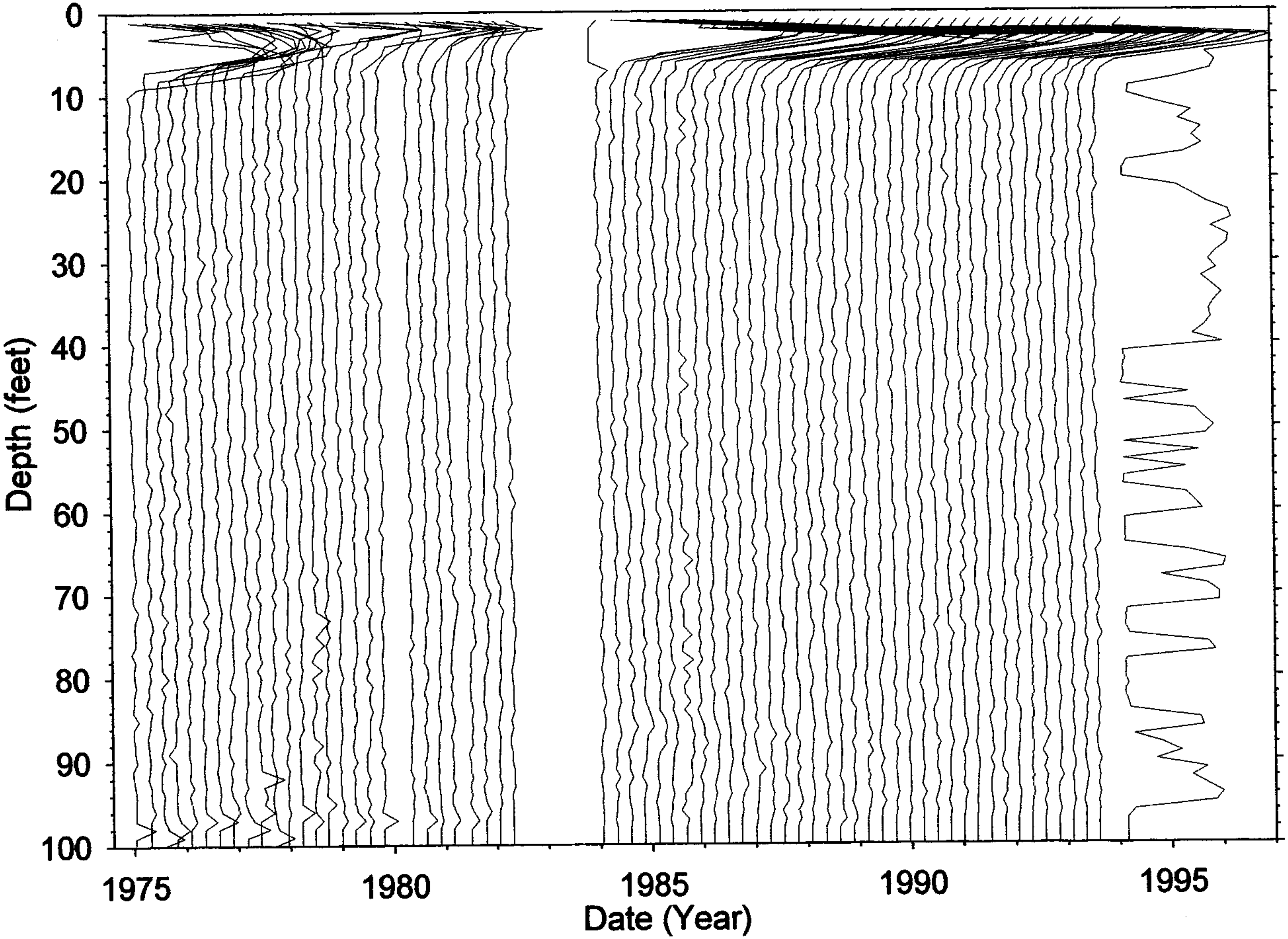
Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 Tank Farm Activity	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	



01/10/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Borehole 22-05-01
Depth: 0-10 ft
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
04/22/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)

Borehole 22-05-01



Borehole 22-05-05

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity

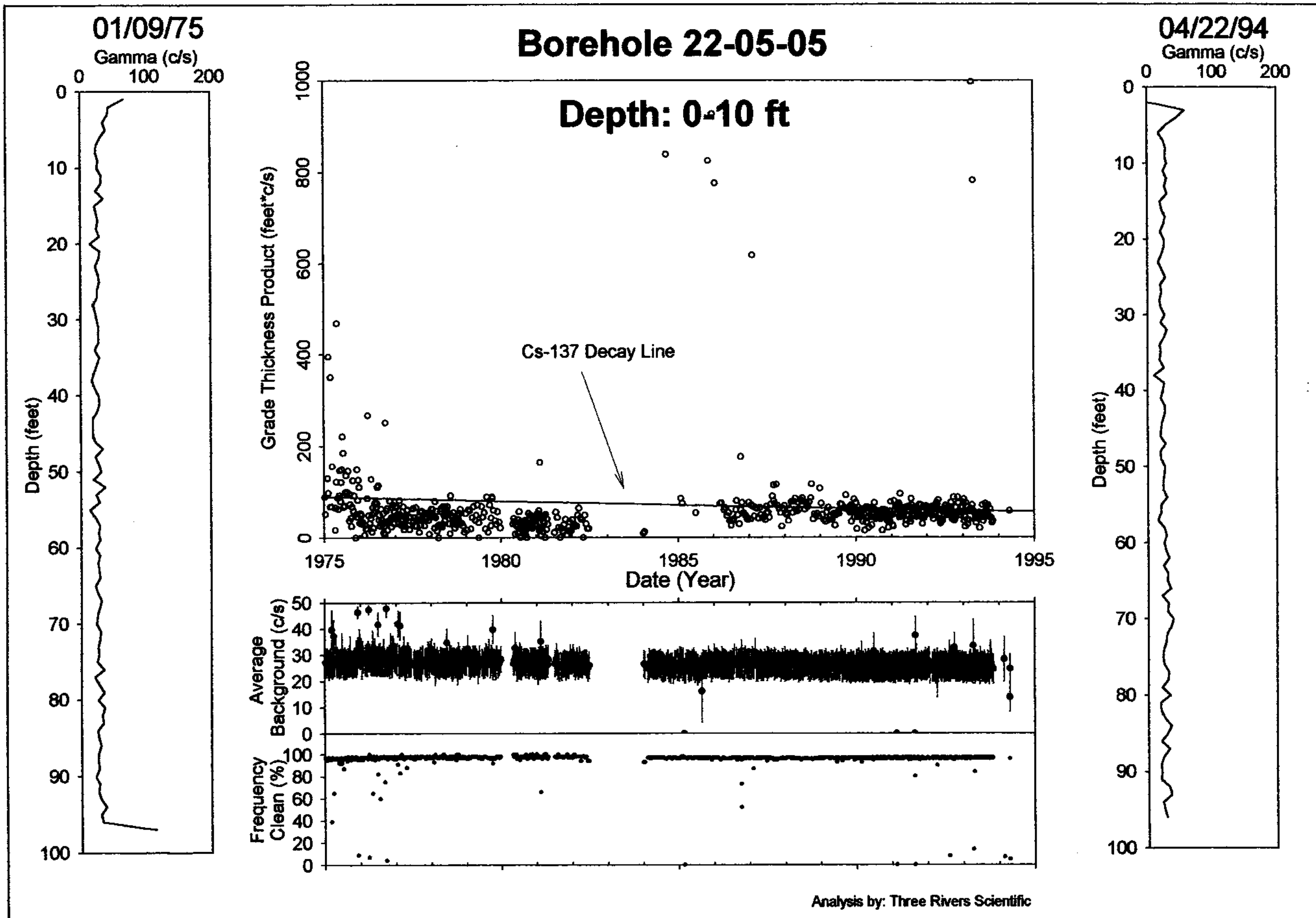
Grade thickness product Cs-137 (HPGe identified) from 0 to 10 feet is erratic indicative of tank farm activities such as transfer line operations. There is also some indication of problems associated with depth control near the surface.

Gross Gamma Survey Information

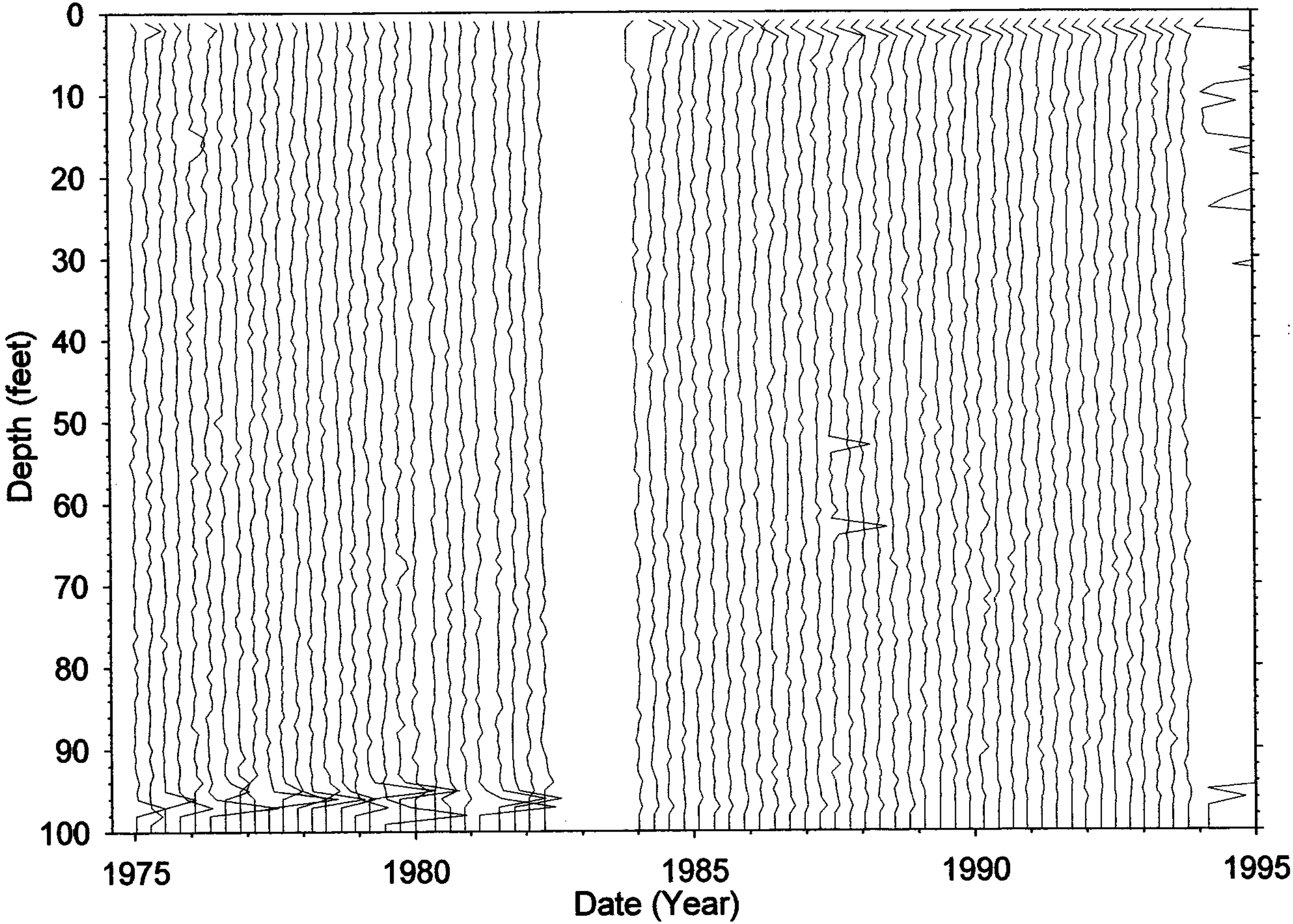
Probe Type :	04: NaI
Other Probe Types :	03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/9/1975
Last Survey Date :	4/22/1994
Number Surveys :	704

Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 Tank Farm Activity	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	


Borehole 22-05-05
Depth: 0-10 ft
01/09/75
Gamma (c/s)
0
100
200
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
Grade Thickness Product (feet*c/s)
1000
800
600
400
200
0
Cs-137 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average Background (c/s)
50
40
30
20
10
0
Frequency Clean (%)
100
80
60
40
20
0
04/22/94
Gamma (c/s)
0
100
200
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
Analysis by: Three Rivers Scientific

Borehole 22-05-05



00 247

HNF-3532 -REV0

Borehole 22-05-09

Contamination (Co-60) from 55-66 feet is Unstable Early
Contamination (Co-60) from 55-90 feet is Unstable Early, Undetermined Late

Grade thickness product Co-60 (HPGe identified) from 55 to 66 feet appears stable from 1977 to 1994, and the rapid change before 1977 could be movement or a rapid decay component. The stack plot clearly displays downward movement from a peak at 70 feet down, and after 1985 there is not enough signal to determine if the movement down continues. The grade thickness product is processed for 55 to 66 feet in order to view stability after possible movement down clears out of the region.

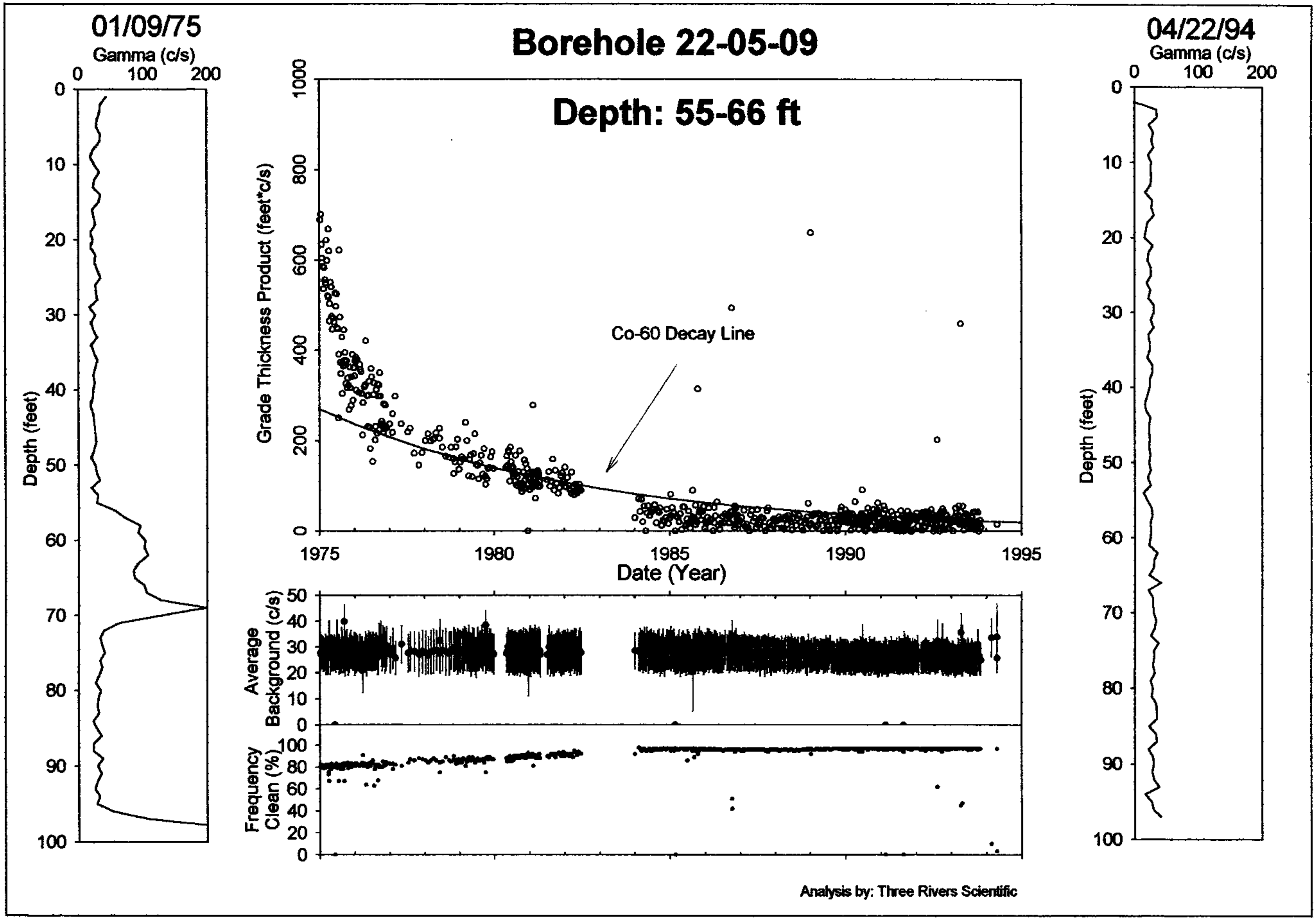
The stack plot clearly shows downward movement of the peak at 70 feet. After 1984, the levels are too low to make a determination of continued movement from the stack plot. Therefore, a grade thickness product is computed for the entire interval of 55 to 90 feet to quantitatively assess the dynamics after 1984. The trend does not clearly match the Co-60 decay from 1984 to 1994, but the deviation is near threshold at the end and a definitive classification is not possible.

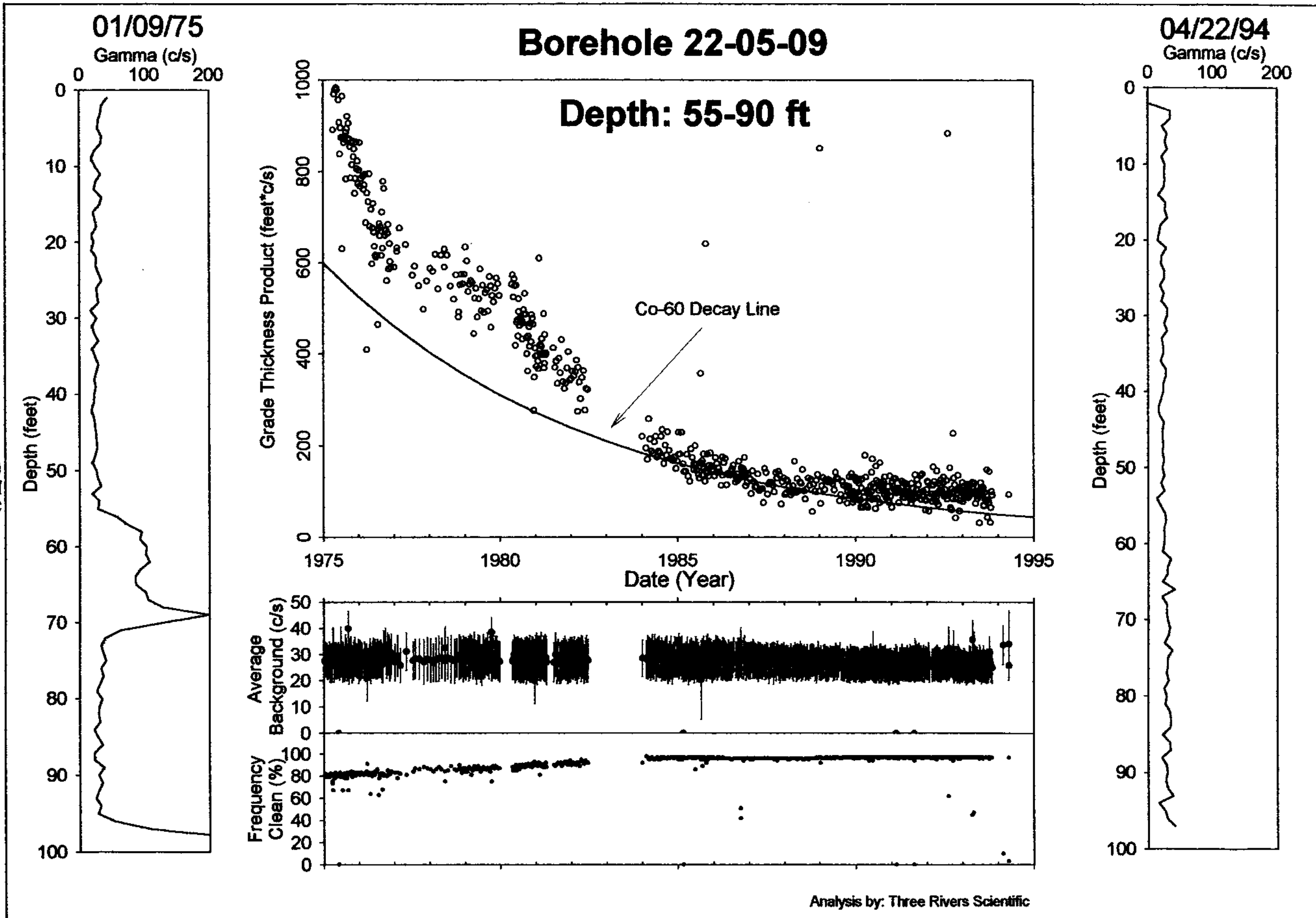
Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	02: Red GM & 03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/9/1975
Last Survey Date :	4/22/1994
Number Surveys :	643

Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	55-66 & 55-90 UNSTABE EARLY & Downward Movement (Undetermined late)	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	

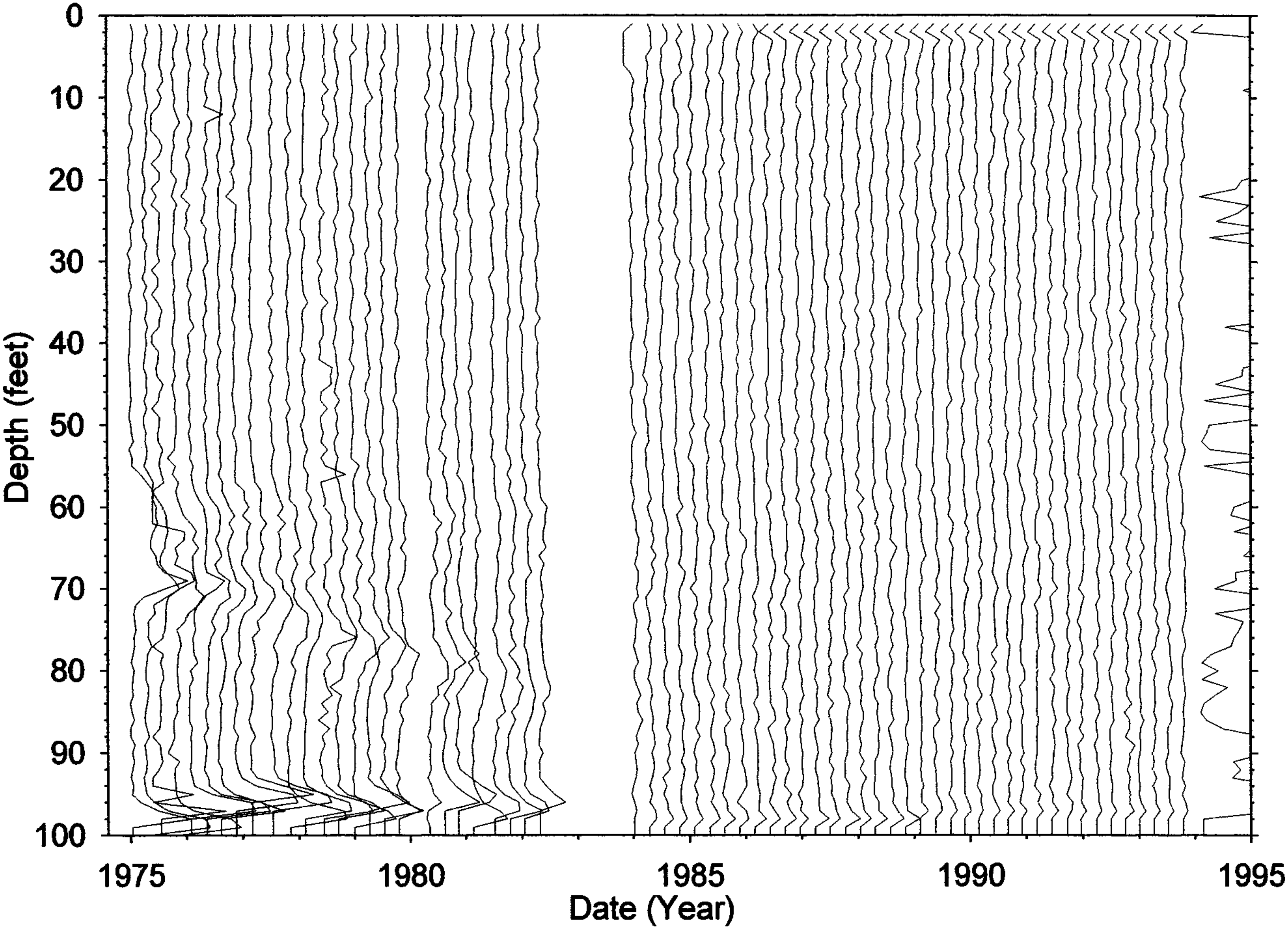

01/09/75
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
Borehole 22-05-09
Depth: 55-66 ft
Grade Thickness Product (feet*c/s)
0 200 400 600 800 1000
Co-60 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
04/22/94
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100



00 250

HNF-3532 - REV 0

Borehole 22-05-09



BY

Dry Well Survey Analysis - Notes

Borehole 22-05-01 Total # Surveys 744 Probe Type 04

neutron surveys 7 # GR Surveys 737

Log Date: 1-10-75 1st 4-22-94 Last Presentation Plot Dates

(If different from 1st & Last)

Contamination Zone Depth(s):

Isotope from Spectral Survey: Cs low Co@bottom Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			Stack → 0-10'

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Analyst Name Bruce Randall S/W ver TFGR0522

BY

Dry Well Survey Analysis - Notes

Borehole 22-05-05 Total # Surveys 708 Probe Type 04

neutron surveys 4 # GR Surveys 704

Log Date: 1-9-75 1st 4-22-94 Last Presentation Plot Dates

(If different from 1st & Last)

Contamination Zone Depth(s):

Isotope from Spectral Survey: Cs Surf & low all depth Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			0-10 90-100

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Example of GTP all well = Bkg + Cs

TF activity but depth problems also

Analyst Name [signature]

S/W ver TFGROSS 2.2

Dry Well Survey Analysis - Notes

Borehole 22-05-09 Total # Surveys 648 Probe Type 04 02

\# neutron surveys 4 # GR Surveys 643

Log Date: 1-9-75 1st 4-22-94 Last Presentation Plot Dates

(If different from 1st & Last)

Contamination Zone Depth(s):

Isotope from Spectral Survey: Cs & Co ≅ 60' Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			55-75 doublet early rapid decay

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Stack shows down movement 55-90

Tried Bkg fit, Method, for 55-90 ft - still no good match

Analyst Name [signature] S/W ver TFGROSS 2.2

filein := "two55-90.txt" **Well 21-05-09**

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

N := last(yr) N = 394 i := 0..N k := 0..300 j := 0..299 $\tau eu := 5.27$

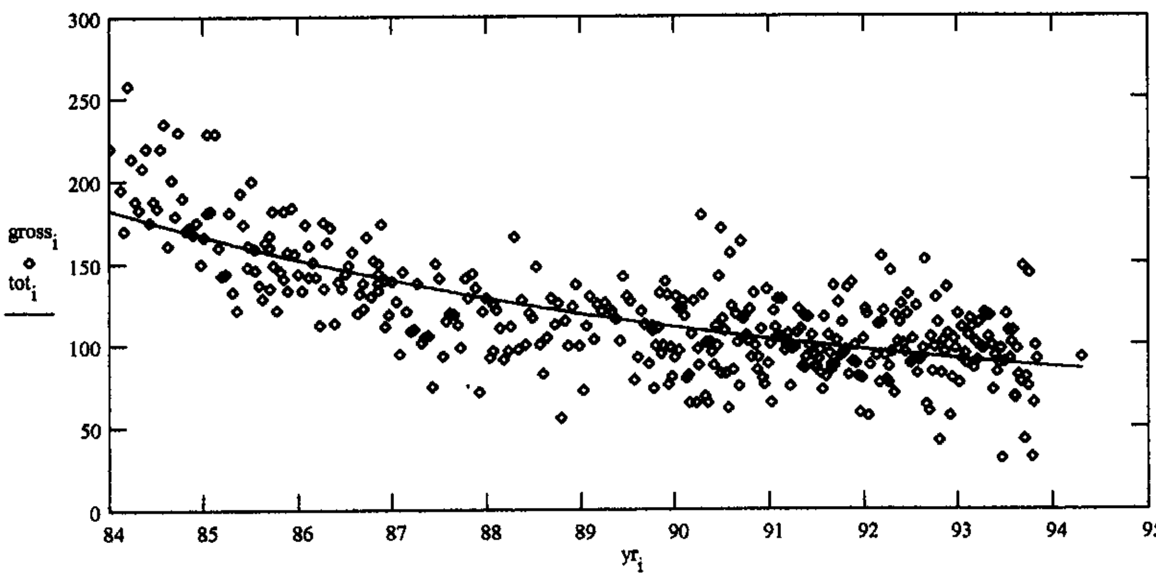
$\tau co := 5.27$ $\tau cs := 3\cdot 10^9$ aco := 00 acs := 52 Eu variables are Ru-106 aeu := 427

$$Cs_i := acs\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \qquad Co_i := aco\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \qquad Eu_i := aeu\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}\cdot 1 \qquad tot_i := Cs_i + Eu_i$$

Cs variables are Bkg

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

ssq(acs, aeu) = 0 1 = 1

$$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := \mathrm{Minerr}(acs, aeu)$$

$\alpha cs = 51.942$ $\alpha eu = 425.811$
U-238 Sb-125

$$\frac{\alpha cs}{\alpha eu} = 0.122$$

$$Cs_i := \alpha cs\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \qquad Eu_i := \alpha eu\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \qquad tot_i := Cs_i + Eu_i$$

$$\frac{Eu_N}{Cs_N} = 0.647$$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop55-90.txt") := out

Borehole 22-06-01

Contamination (Cs-137) from 0-8 feet is Tank Farm Activity
Contamination (Sb-125) from 42-52 feet is Stable
Contamination (Co-60 & Ru-106) from 52-65 feet is Stable

Grade thickness product Cs-137 (HPGe identified) from 0 to 8 feet is erratic indicative of tank farm activities such as transfer line operations.

Grade thickness product Sb-125 (hypothesis) from 42 to 52 feet is stable from 1975 to 1994. The levels are near threshold early, and at background late. Co-60 is HPGe identified, but at levels too low to register with gross gamma.

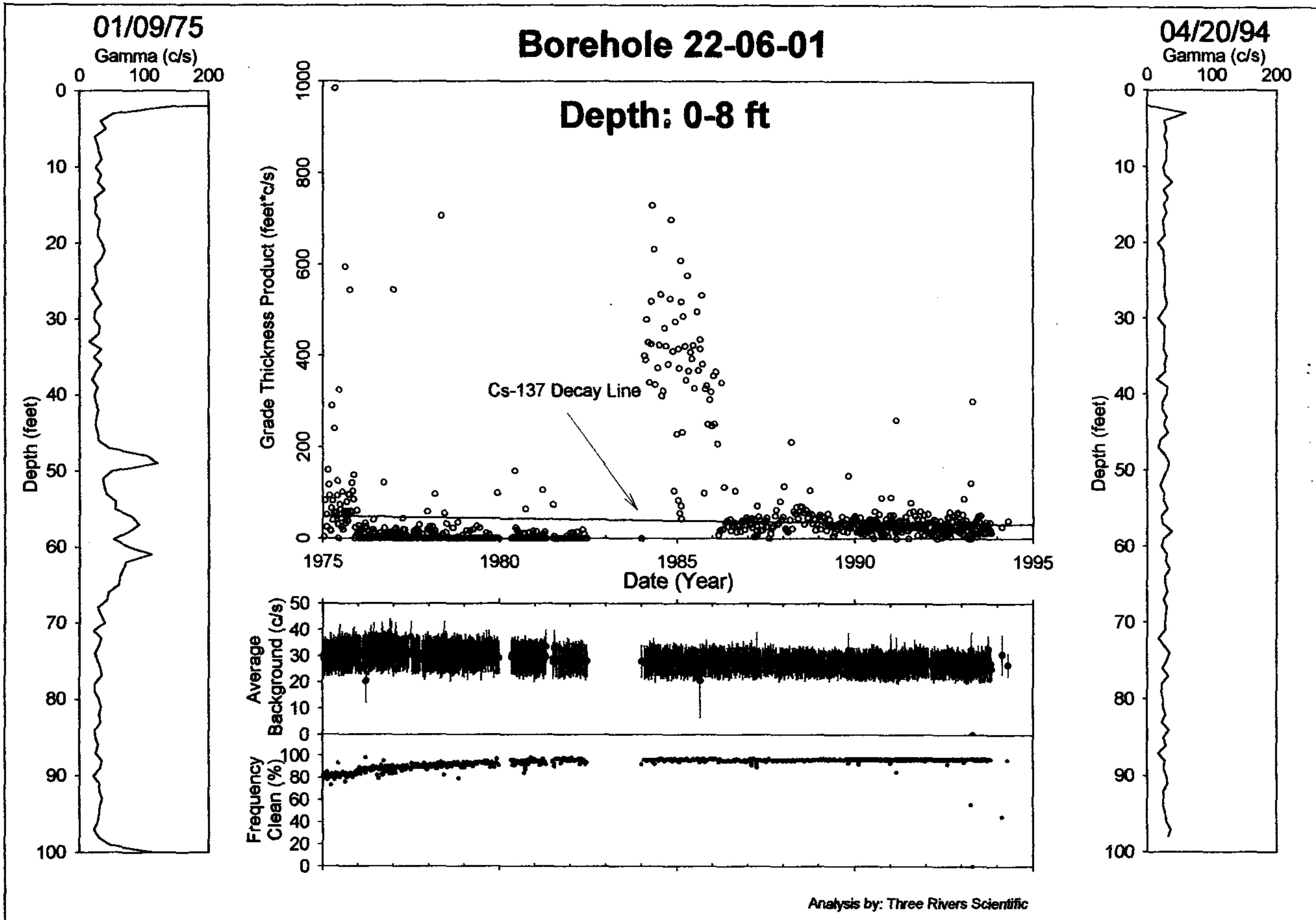
Grade thickness product is consistent with a least squares fit for Co-60 (HPGe identified) and Ru-106 (hypothesis). The least squares fit results in gross gamma contribution ratio of Co-60 to Ru-106 of 1.07 as of Jan 1975.

Gross Gamma Survey Information

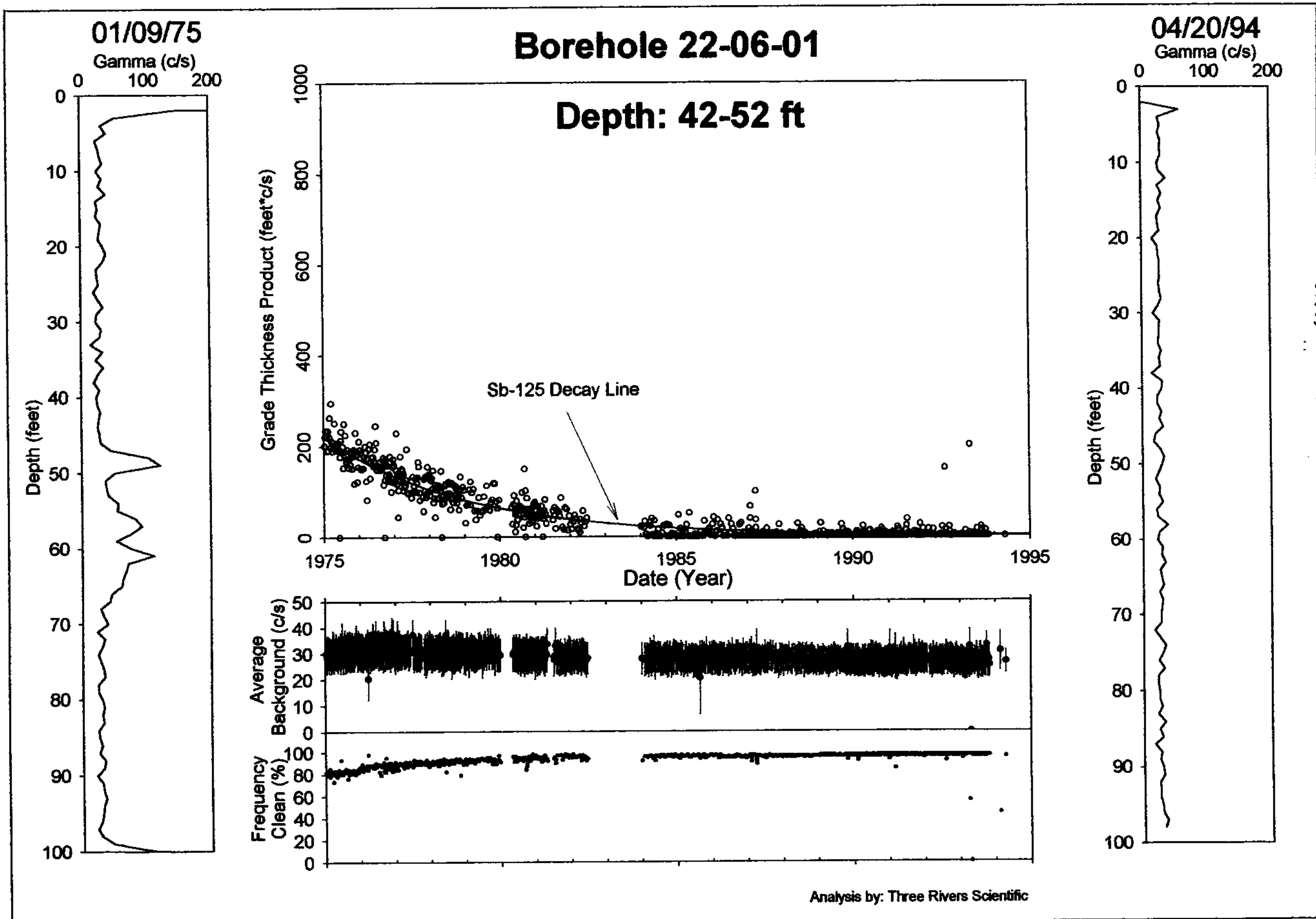
Probe Type :	04: NaI
Other Probe Types :	02: Red GM & 03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/9/1975
Last Survey Date :	4/20/1994
Number Surveys :	726

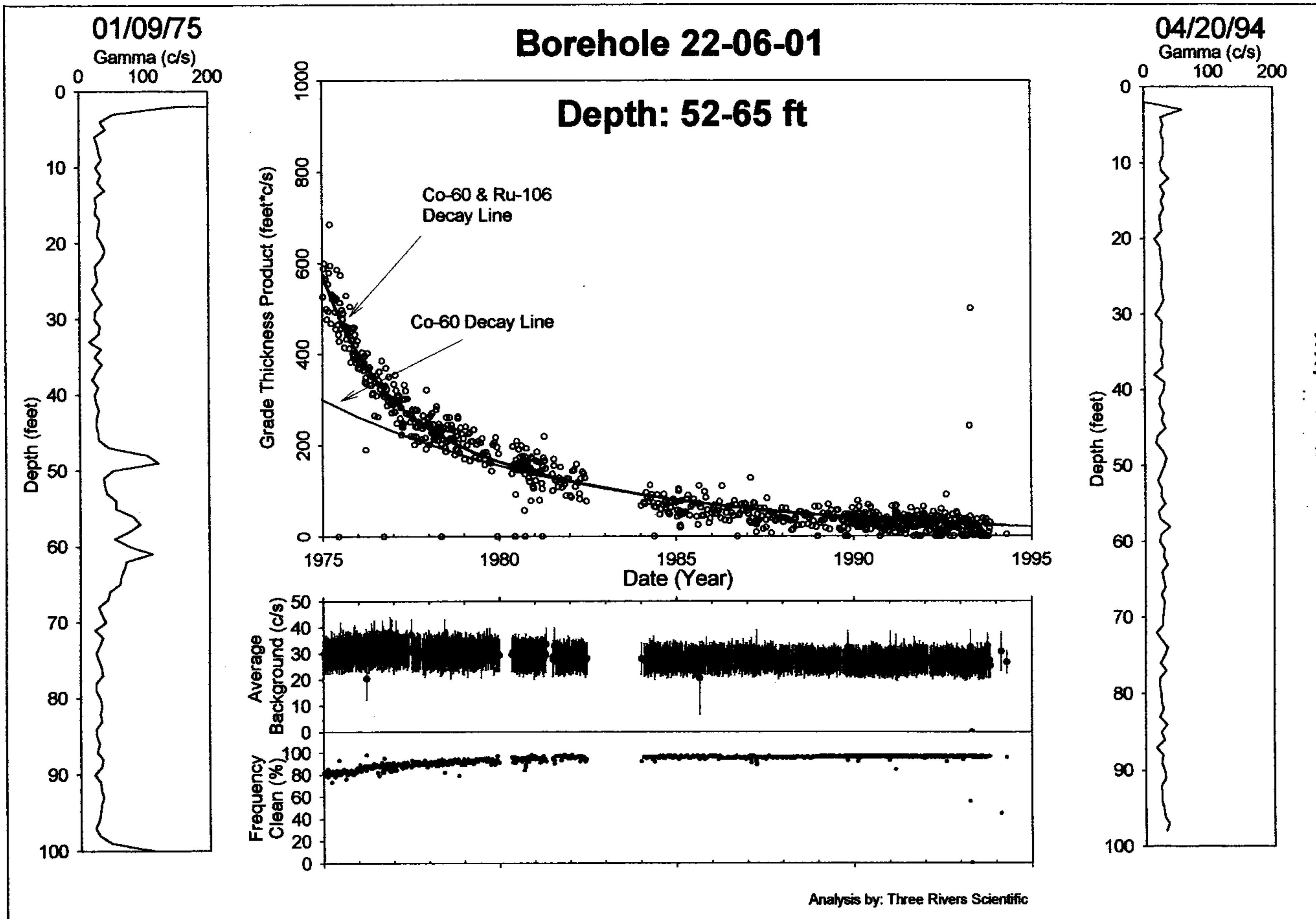
Analysis Notes

Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-8 Tank Farm Activity 42-52 & 52-65 Stable	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	

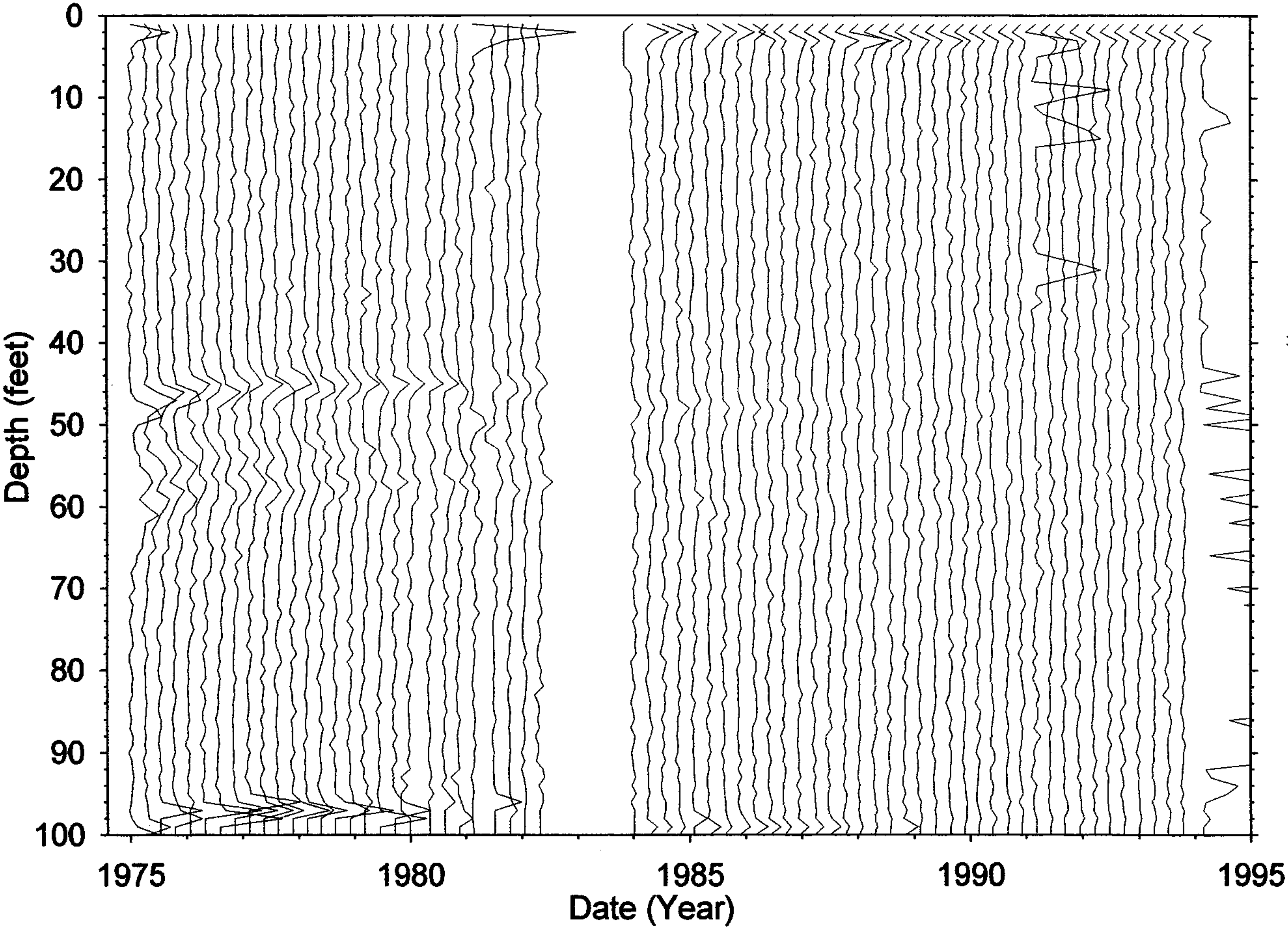

Borehole 22-06-01
Depth: 0-8 ft
01/09/75
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
04/20/94
Analysis by: Three Rivers Scientific

Borehole 22-06-01




Borehole 22-06-01
Depth: 52-65 ft
01/09/75
Gamma (c/s)
Depth (feet)
04/20/94
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Co-60 & Ru-106 Decay Line
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

Borehole 22-06-01



HNF-3532 -REV0

Borehole 22-06-05

Contamination (Cs-137) from 0-8 feet is Tank Farm Activity
Contamination (Sb-125 & Co-60) from 28-36 feet is Stable
Contamination (Sb-125 & Co-60) from 36-50 feet is Unstable Early (Down Movement)
Contamination (Co-60) from 62-84 feet is Unstable (Down Movement)
Contamination (Co-60) from 28-84 feet is Unstable (Down Movement)*

*Zone used to assess downward migration

Grade thickness product Cs-137 (HPGe identified) from 0 to 8 feet is erratic indicative of tank farm activities such as transfer line operations. However, the majority of history is low level.

Grade thickness product from 28 to 36 feet is consistent with a least squares fit of Sb-125 (hypothesis) and Co-60 (HPGe identified) decay from 1975 to 1994. The gross gamma contribution ratio of Sb-125 to Co-60 is 0.54 on 4/20/94.

The stack plot clearly shows downward contaminant movement from 40 to 84 feet. Grade thickness product from 36 to 50 feet is computed and displayed on expanded scale in order to assess the later years for stability after the front may have passed through. After 1981 through 1993, the grade thickness product is consistent with least squares fit of Sb-125 (hypothesis) and Co-60 (HPGe identified) from 36 to 50 feet. Given the presence of Sb-125, the conclusion is that after the contaminant front moved through this zone a stable residual of Sb-125 and Co-60 remain. The gross gamma contribution ratio of Sb-125 to Co-60 is 6.5 as of 4/20/94.

As the contaminant front moves below 62 feet, there is clear indication of possible hang-up at 62 feet. Therefore, a grade thickness product was computed for 62 to 84 feet in order to assess the later years for stability after the front moved into the zone. This interval covers the deepest depth for the front advancement, as of the data collection. A match to Co-60 (HPGe identified) is not clear, and at most only for the last 2 years. This indicates that from 1987 to 1992 there may be lateral influx into this interval as well as downward movement.

Grade thickness product from 28 to 84 feet is computed that covers all downward movement span (refer to stack plot). Thus all contaminant intervals is conserved, but the trend does not match an exponential decay except for possibly 1977 to 1980 for a Co-60 decay. Note also some indication of very early increase.

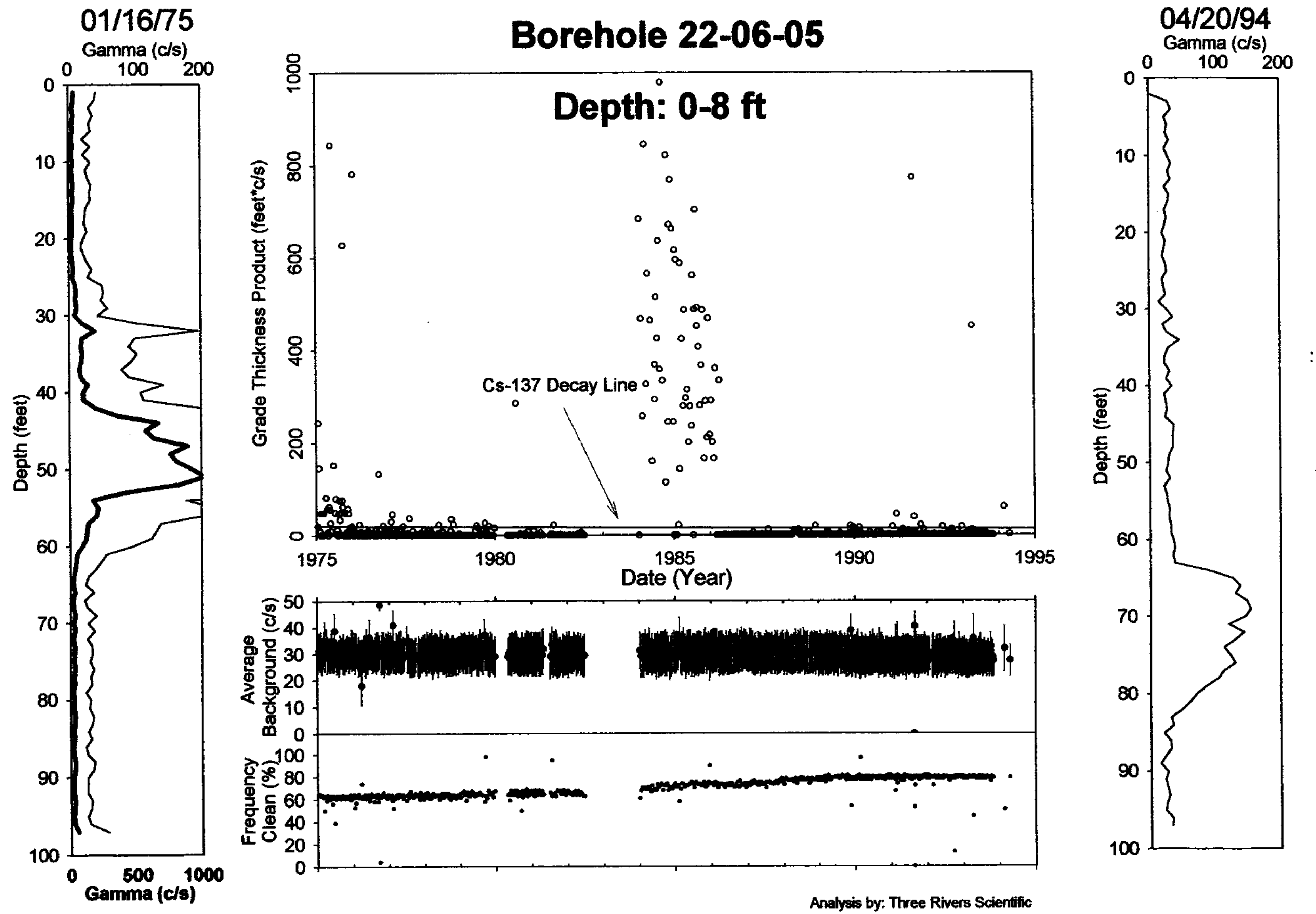
Borehole 22-06-05

Gross Gamma Survey Information

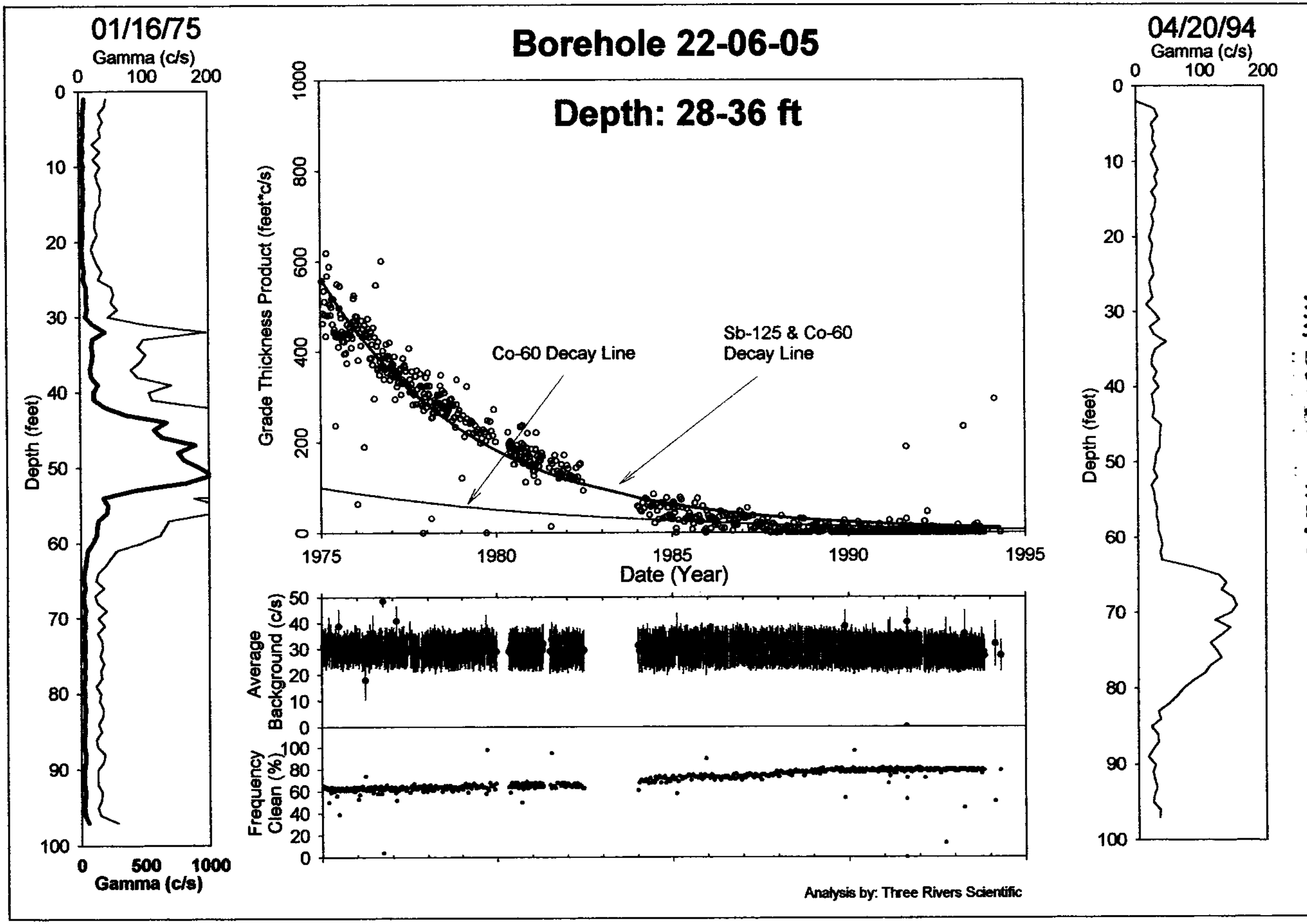
Probe Type :	04: NaI
Other Probe Types :	02: Red GM & 03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/16/1975
Last Survey Date :	4/20/1994
Number Surveys :	718

Analysis Notes

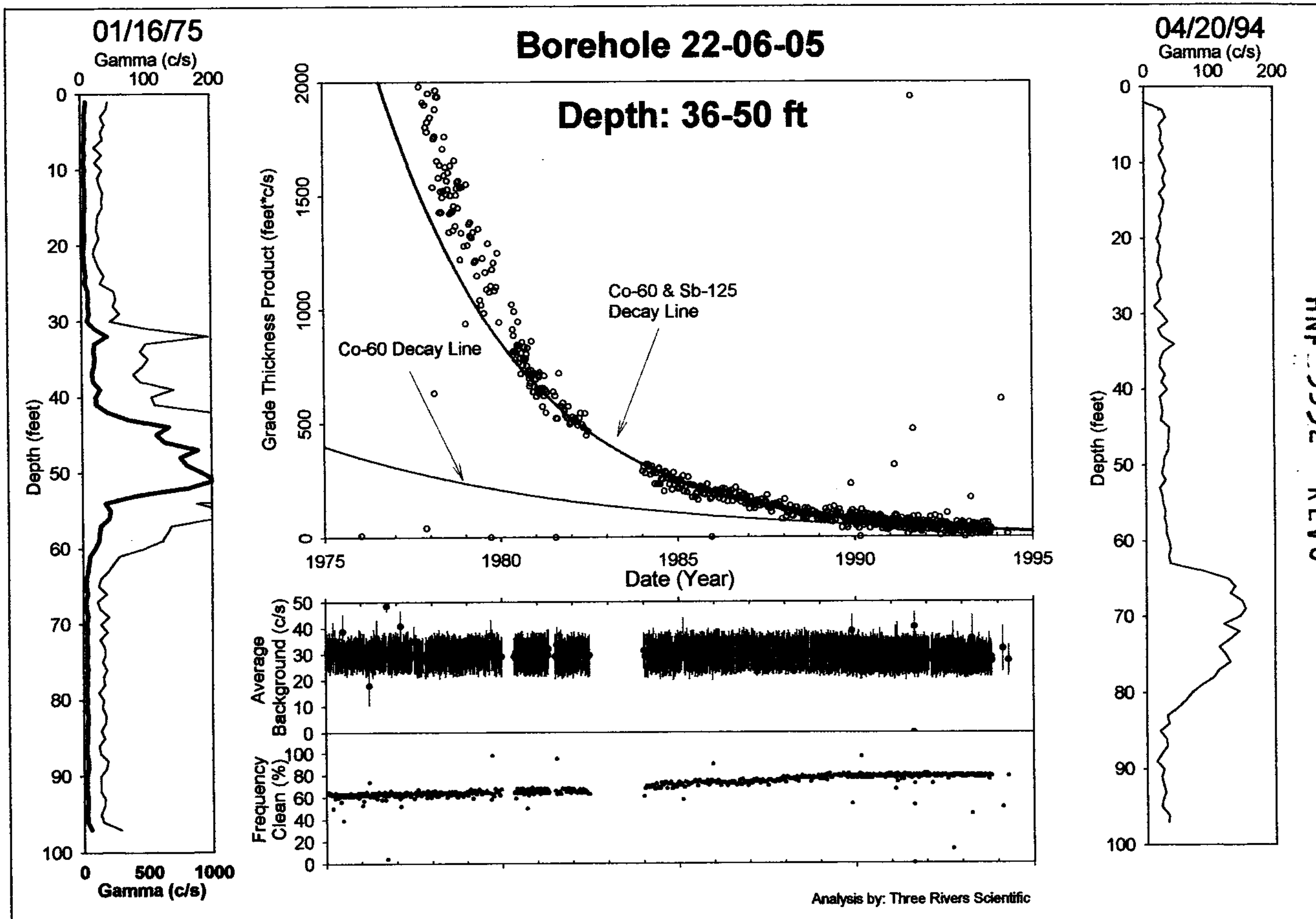
Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-8 Tank Farm Activity 28-36 Stable 36-50 & 62-84 Unstable early (Downward Movement) 28-84 Downward movement not conserved	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	


Borehole 22-06-05
Depth: 0-8 ft
01/16/75
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
0 500 1000
Gamma (c/s)
Grade Thickness Product (feet*c/s)
0 200 400 600 800 1000
Cs-137 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
04/20/94
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100

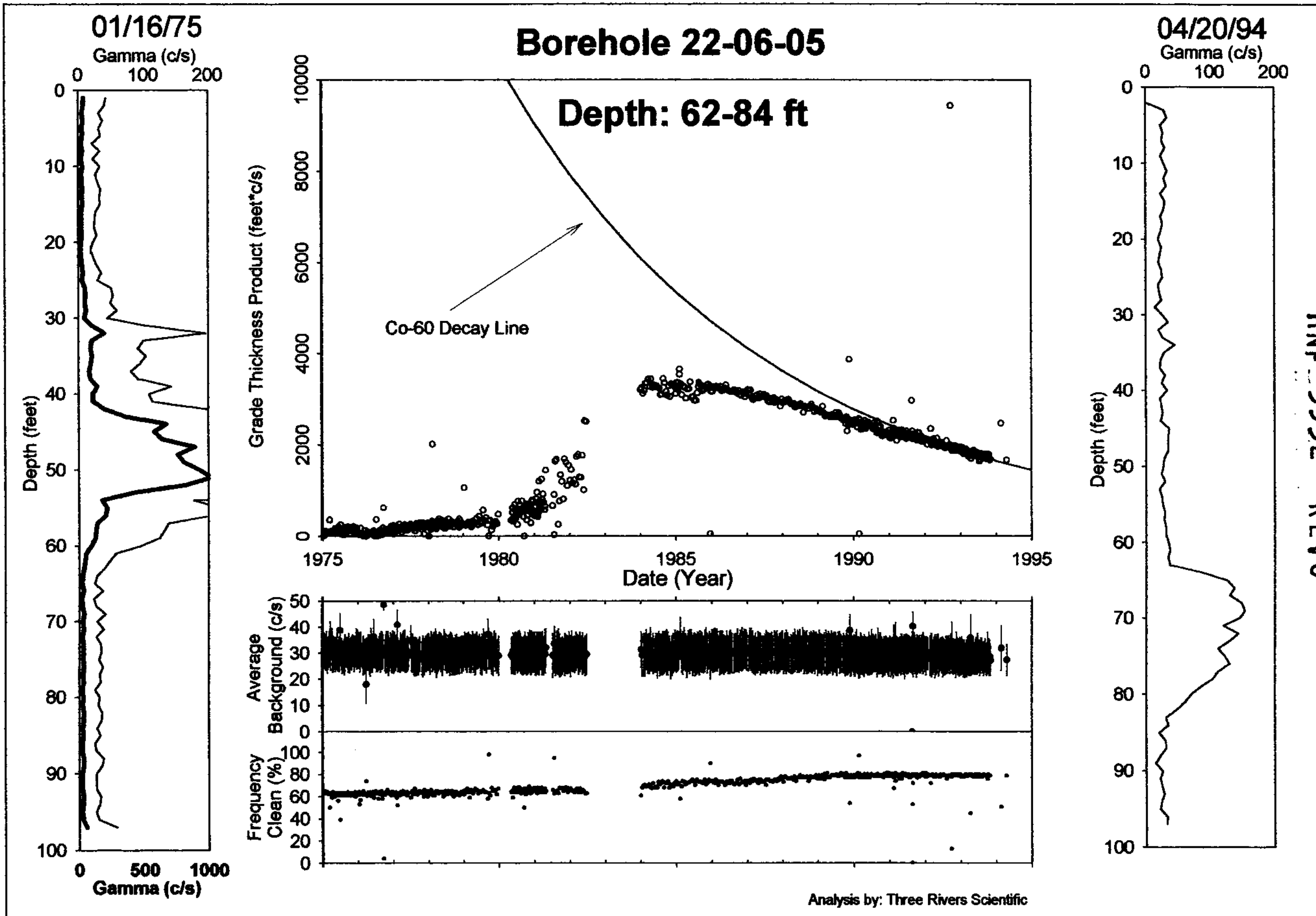
Borehole 22-06-05



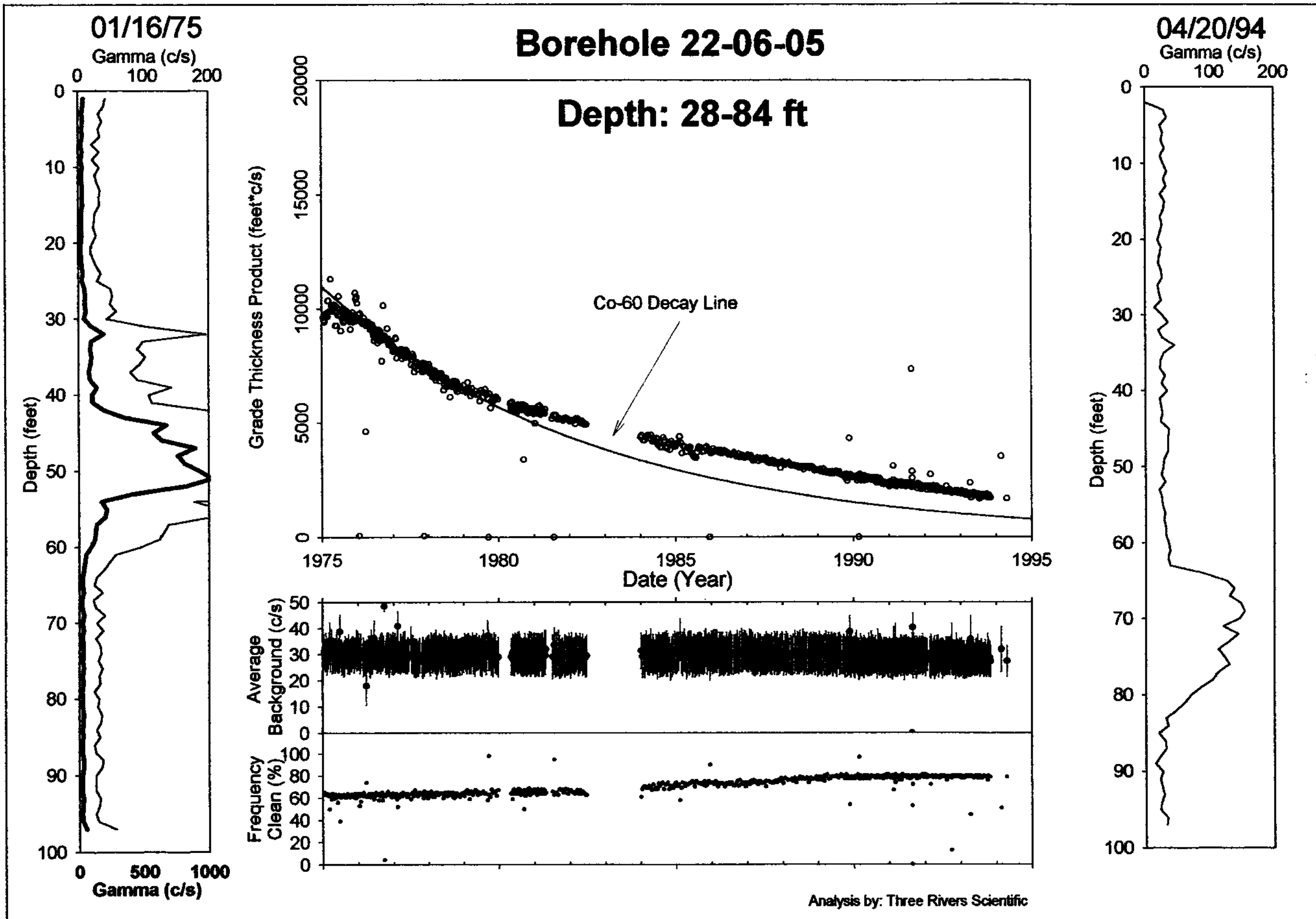
00 264



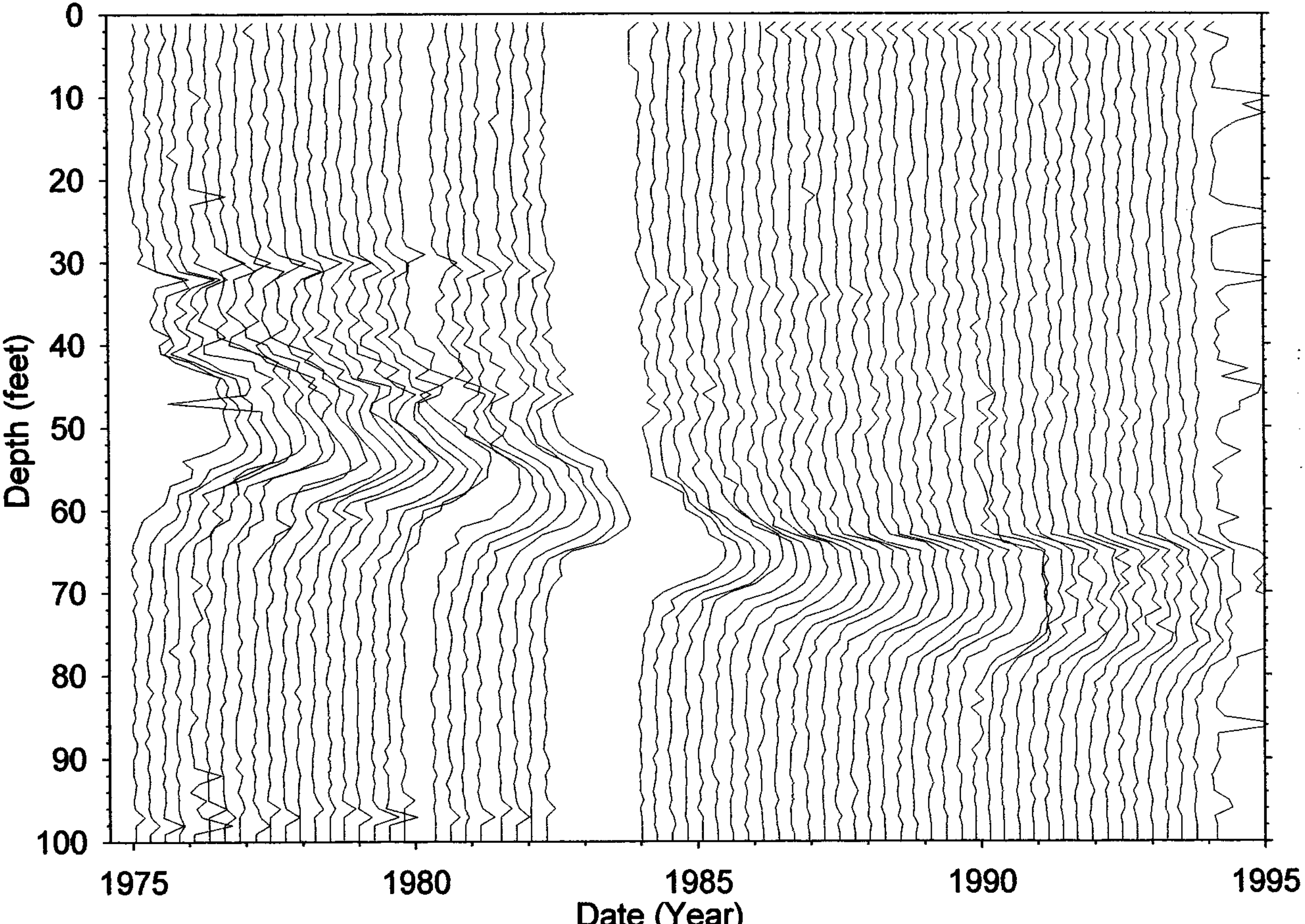
Borehole 22-06-05
Depth: 36-50 ft
01/16/75
Gamma (c/s)
Depth (feet)
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Co-60 & Sb-125
Decay Line
Co-60 Decay Line
Date (Year)
Average
Background (c/s)
Frequency
Clean (%)
04/20/94
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific


01/16/75
Gamma (c/s)
Depth (feet)
Gamma (c/s)
Borehole 22-06-05
Depth: 62-84 ft
Co-60 Decay Line
Grade Thickness Product (feet*c/s)
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
04/20/94
Gamma (c/s)
Depth (feet)

00 266


01/16/75
Gamma (c/s)
0
100
200
Depth (feet)
Gamma (c/s)
0
500
1000
Borehole 22-06-05
Depth: 28-84 ft
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
1975
1980
1985
1990
1995
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
04/20/94
Gamma (c/s)
Depth (feet)

Borehole 22-06-05



HNF-3532 -REV0

00 268

Borehole 22-06-07

Contamination (Cs-137) from 0-8 feet is Tank Farm Activity
Contamination (Cs-137) from 40-52 feet is Unstable Early
Contamination (Co-60) from 52-64 feet is Unstable Early
Contamination (Co-60) from 64-80 feet is Unstable Early
Contamination (Co-60) from 52-80 feet is Unstable Early*

*Zone computed to assess downward movement

Grade thickness product Cs-137 (HPGe identified) from 0 to 8 feet is erratic indicative of tank farm activities such as transfer line operations.

Grade thickness product from 40 to 52 feet is not consistent with Cs-137 (HPGe identified) decay from 1975 to 1985. Since 1985 there is no gross gamma indication of contaminant.

Grade thickness product from 52-64 feet is increasing from 1975 until 1980, refer to stack plot. Since 1985 this interval is decreasing consistent with Co-60 (HPGe identified) until 1994. The rapid increase is followed by a faster decrease than Co-60 decay until onset of stability near 1985. Note Cs-137 is also HPGe identified, but at too low a level to register on the gross gamma.

Grade thickness product from 64-80 feet is increasing from 1975 until 1980, refer to stack plot. Since 1984 this interval is decreasing consistent with Co-60 (HPGe identified) until 1994. Unlike the upper zone, this zone increases asymptotically to stability near 1984. Note Cs-137 is also HPGe identified, but at too low a level to register on the gross gamma.

The grade thickness product for the entire interval from 52 to 80 feet is processed to assess the possibility of downward contaminant movement. Since this complete zone shows an increase from 1995 to 1980, and stability from 1980 to 1994 there is lateral influx into this total interval. Also, the onset of stability is sooner than either sub zone indicates some downward transfer of contaminant between the sub zones.

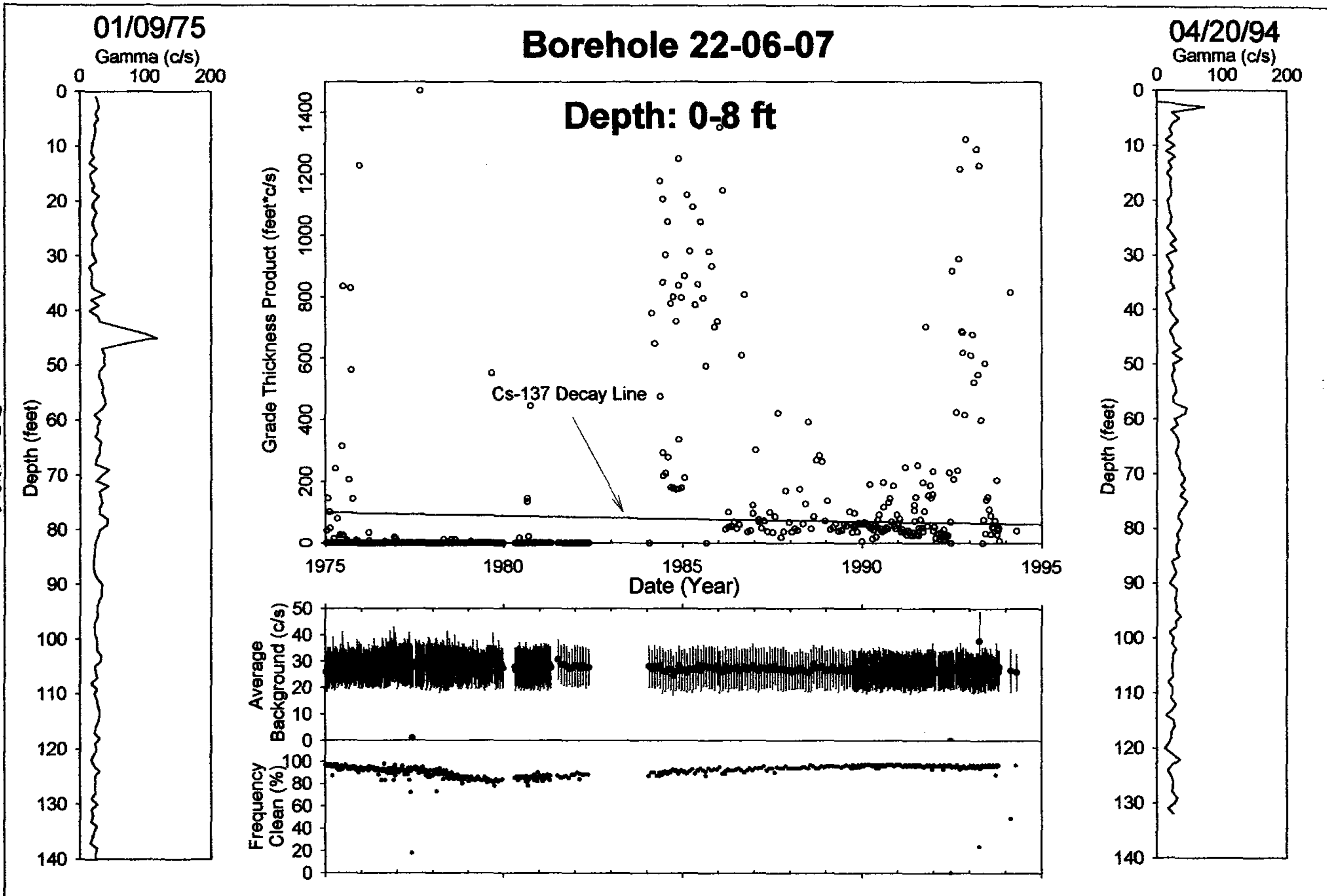
Borehole 22-06-07

Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	02: Red GM & 03: Neutron
Borehole Depth :	140 ft
Survey Depth :	140 ft
First Survey Date :	1/9/1975
Last Survey Date :	4/20/1994
Number Surveys :	535

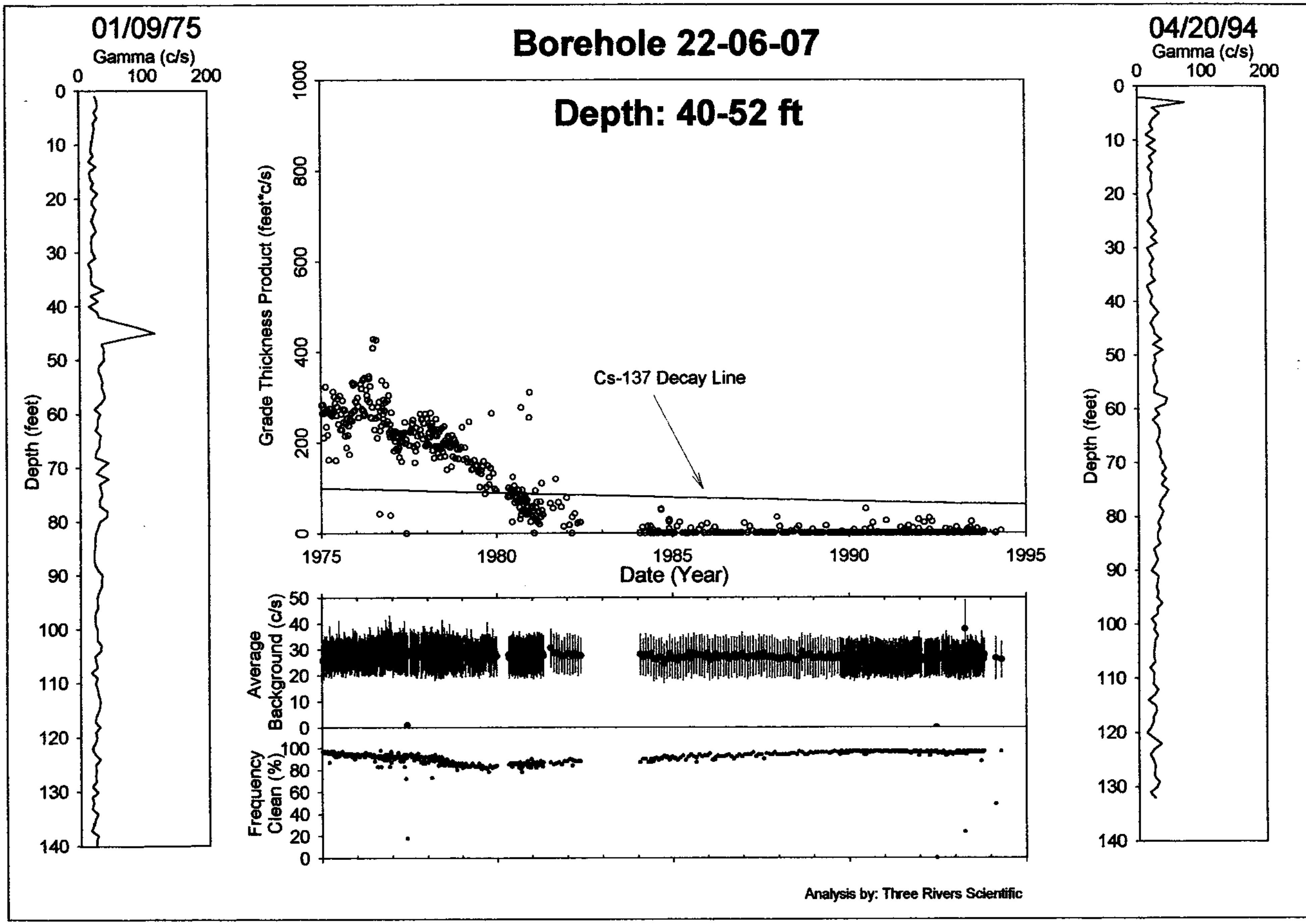
Analysis Notes

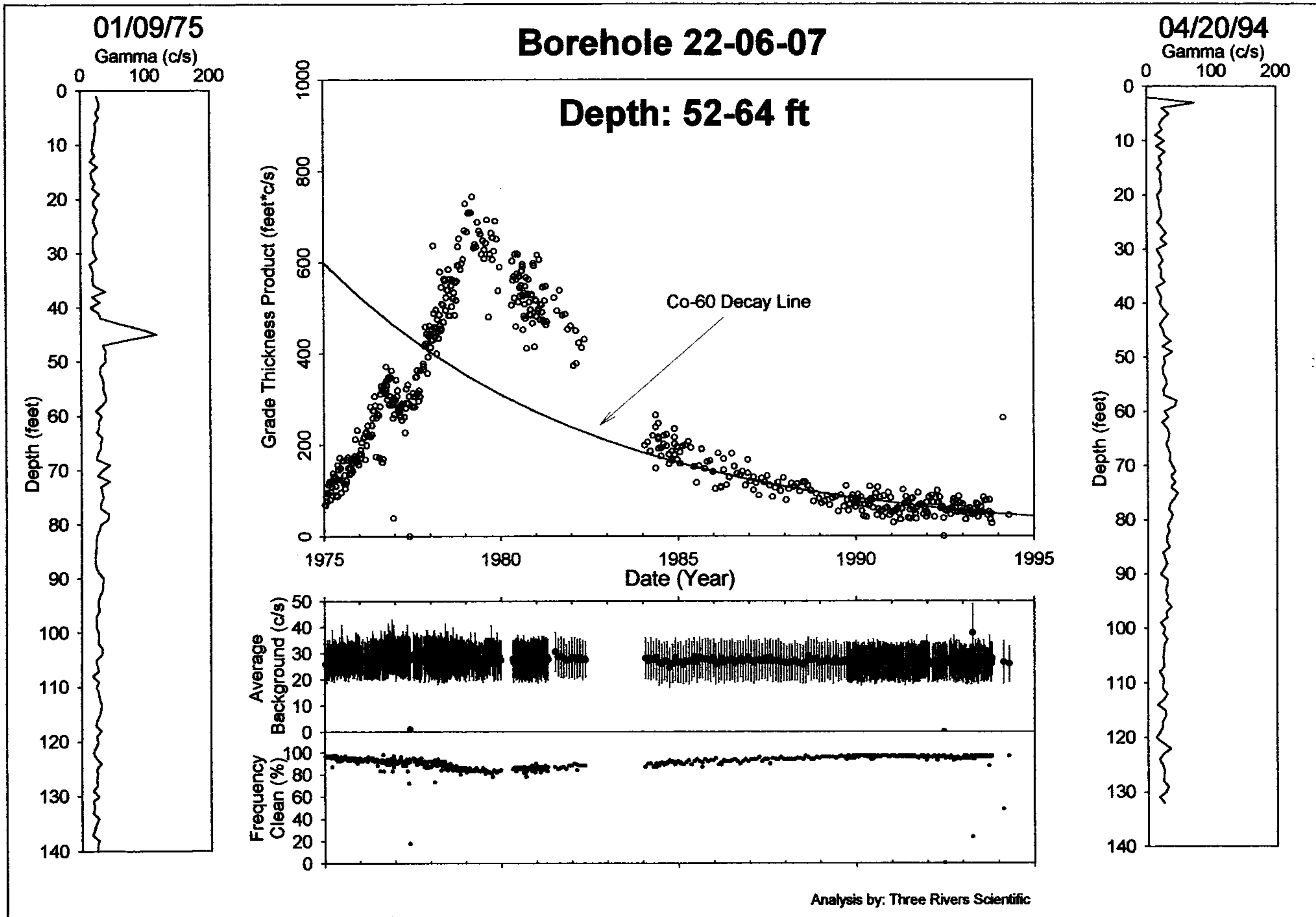
Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-8 Tank Farm Activity 40-52 & 52-64 & 64-80 UNSTABLE Early 52-80 Unstable early (some downward movement)	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	



Analysis by: Three Rivers Scientific

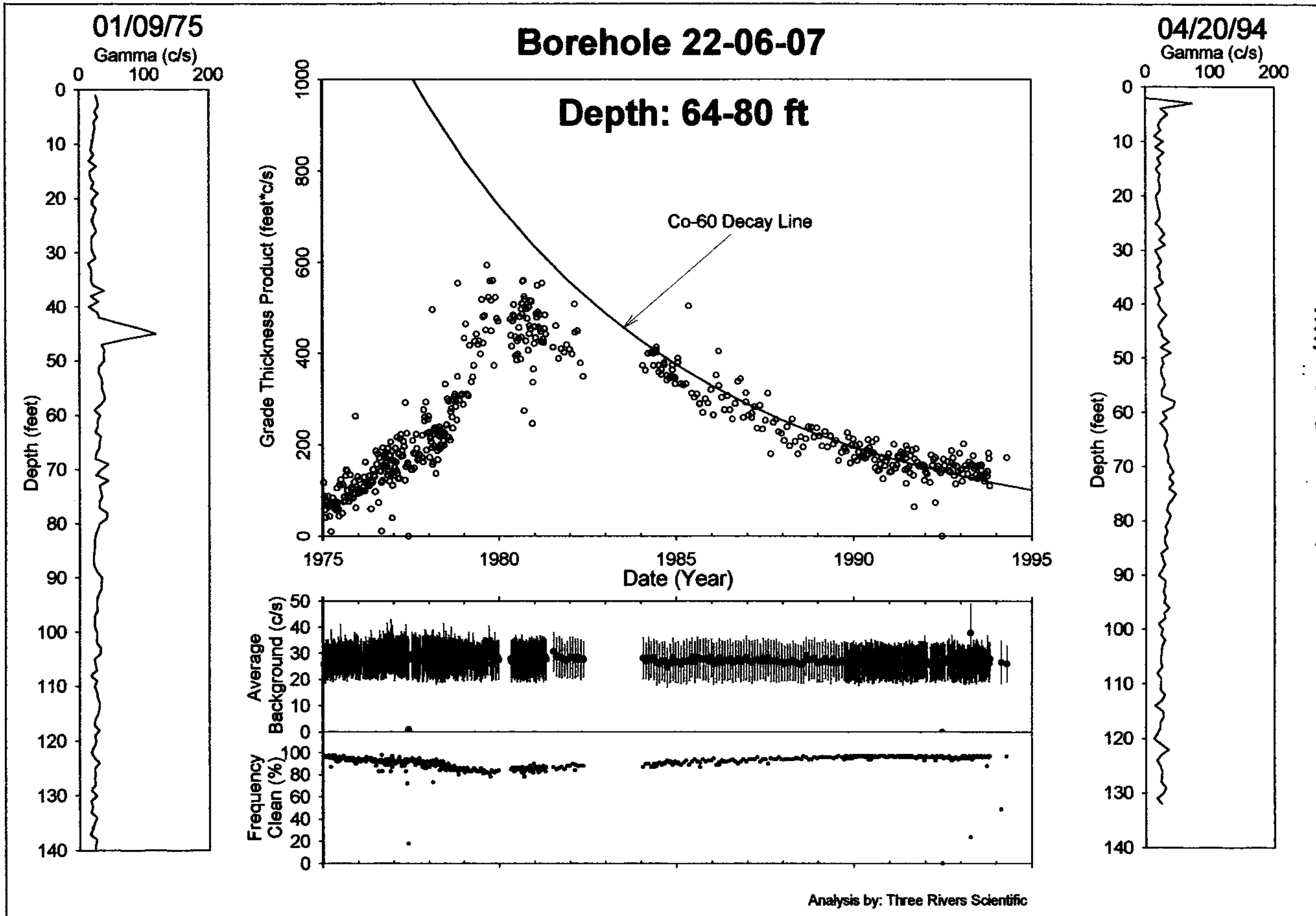
00 271


01/09/75
Gamma (c/s)
Depth (feet)
Borehole 22-06-07
Depth: 40-52 ft
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
04/20/94
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific



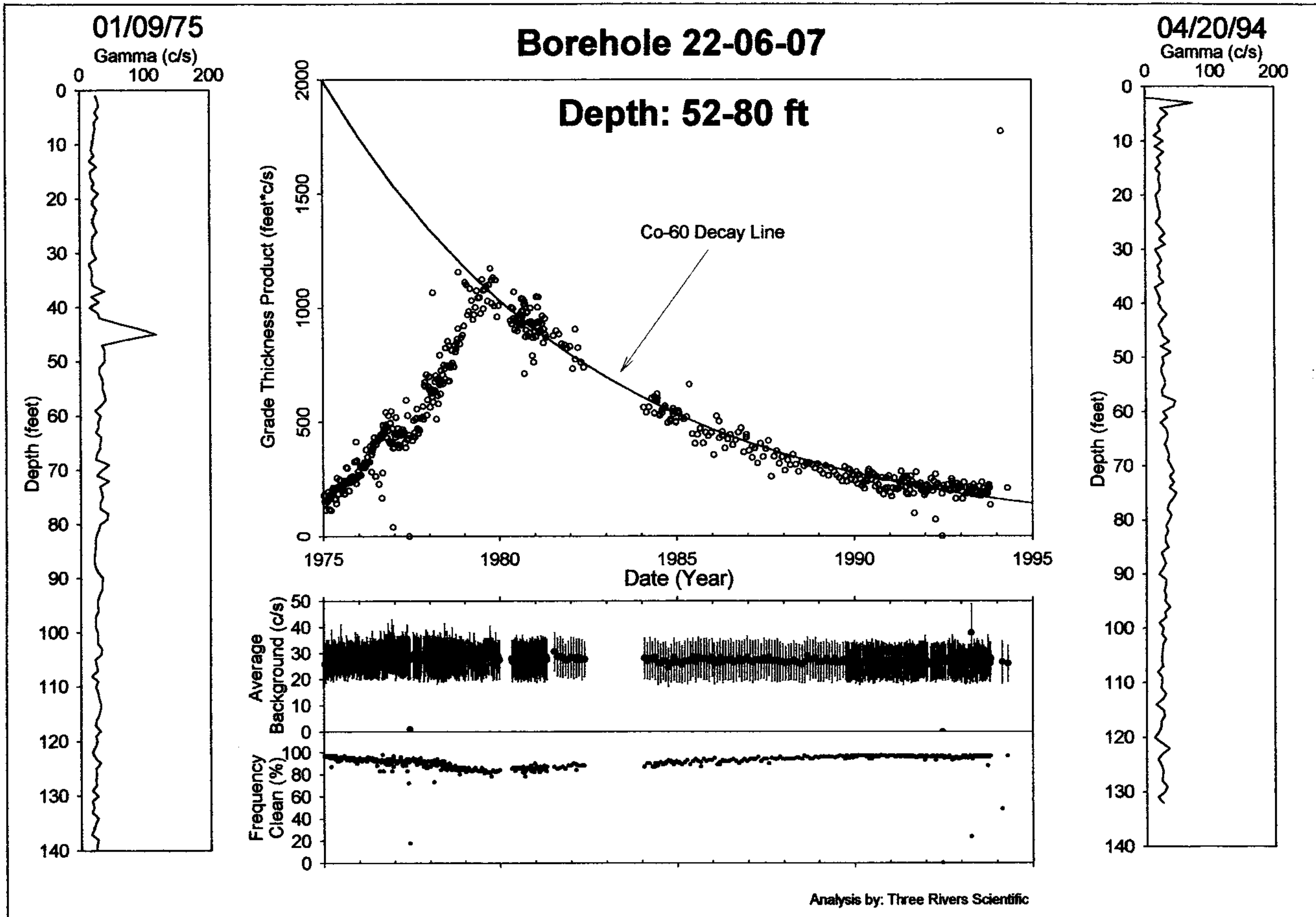
HNF-3532 -REV0

00 273



00 274

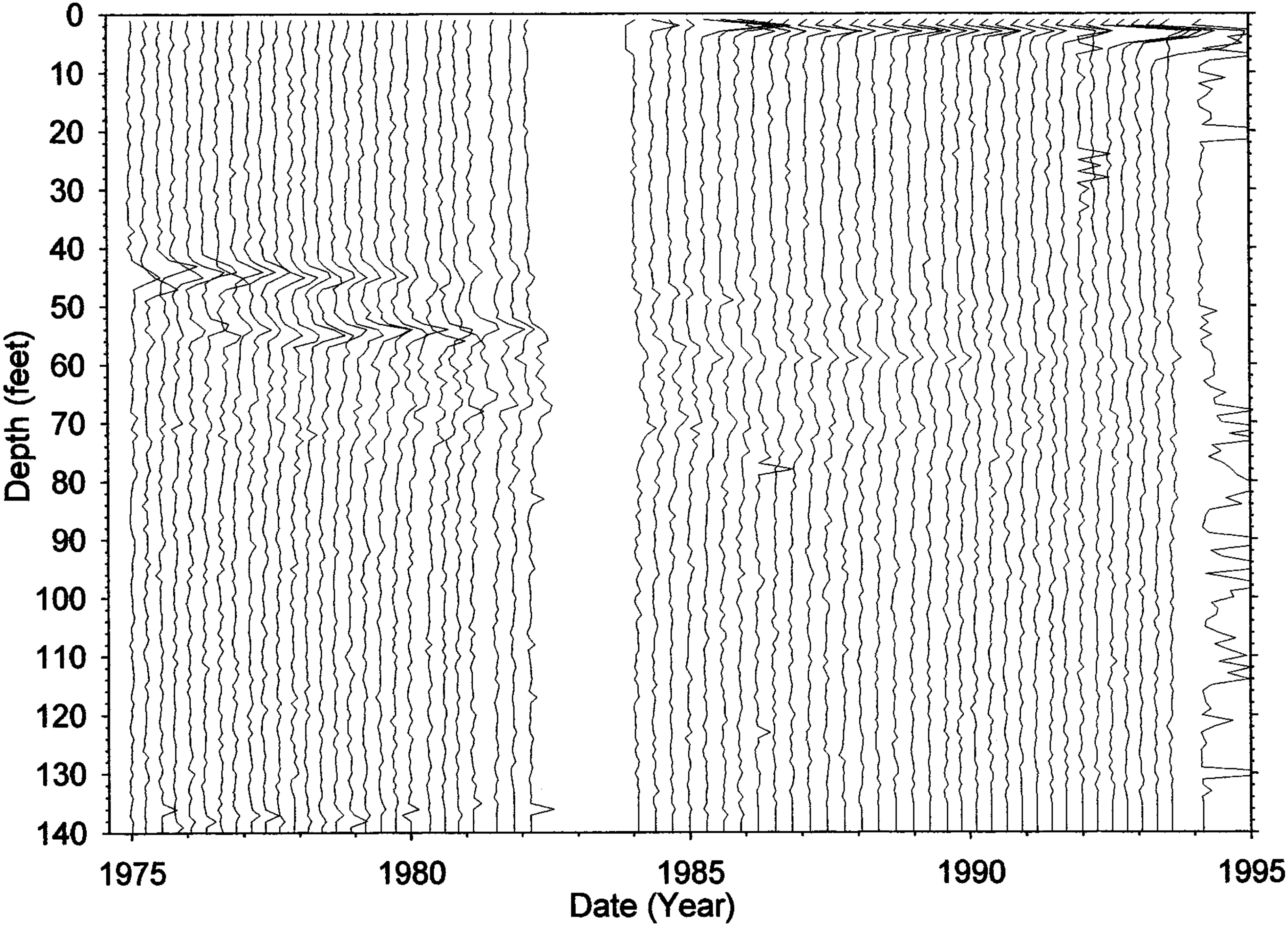
HNF-3532 - REV 0



00 275

HNF-3532 -REV0

Borehole 22-06-07



HNF-3532 -REV0

00 276

Borehole 22-06-09

Contamination (Ru-106) from 70-90 feet is Unstable Early

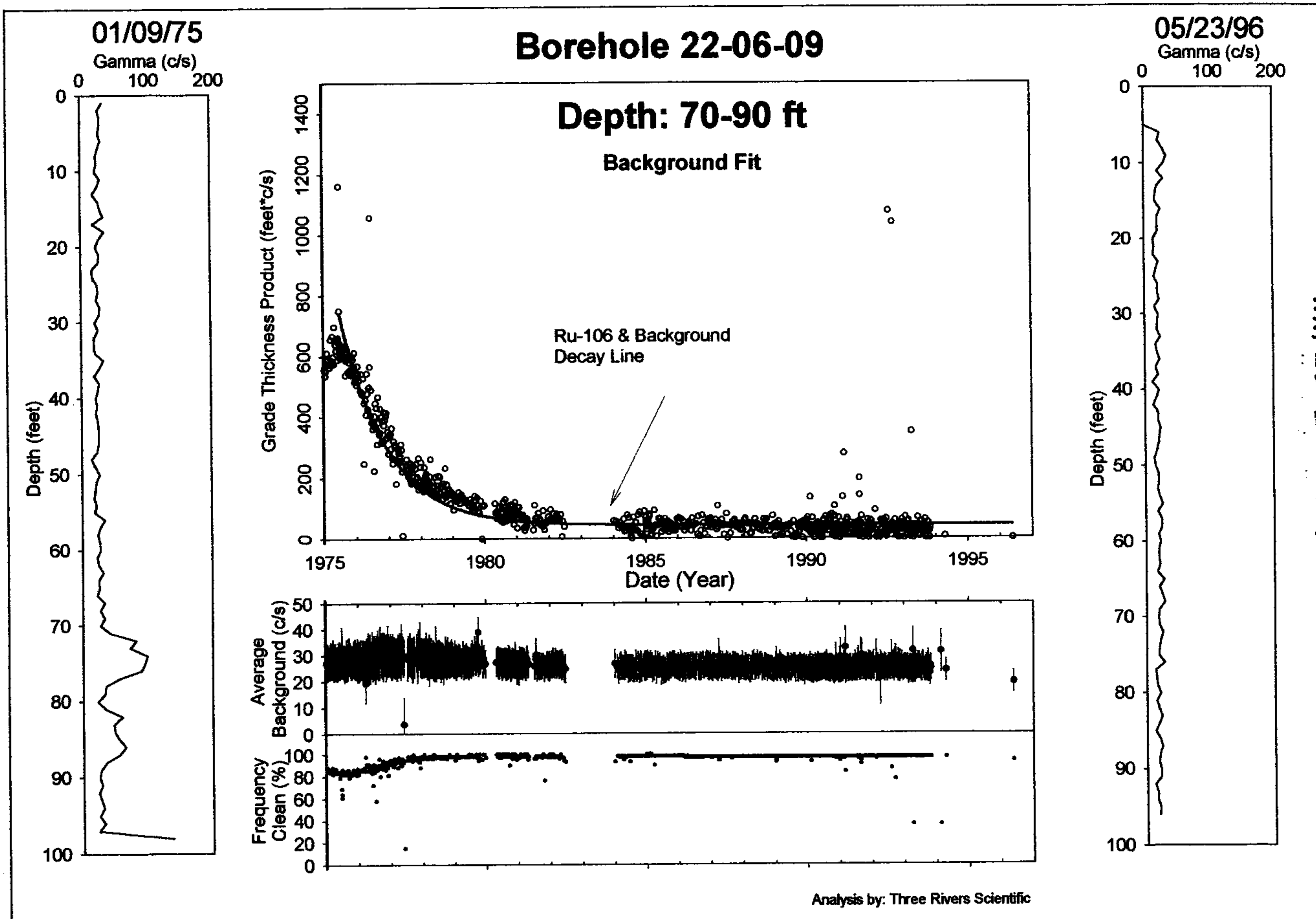
Grade thickness product Ru-106 (hypothesis) from 70 to 90 feet is decreasing consistent with a least squares fit to Ru-106 and a constant background after the initial very short time of increase from 1975 to 1976.

Gross Gamma Survey Information

Probe Type :	04: NaI
Other Probe Types :	02: Red GM & 03: Neutron
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/9/1975
Last Survey Date :	5/23/1996
Number Surveys :	709

Analysis Notes

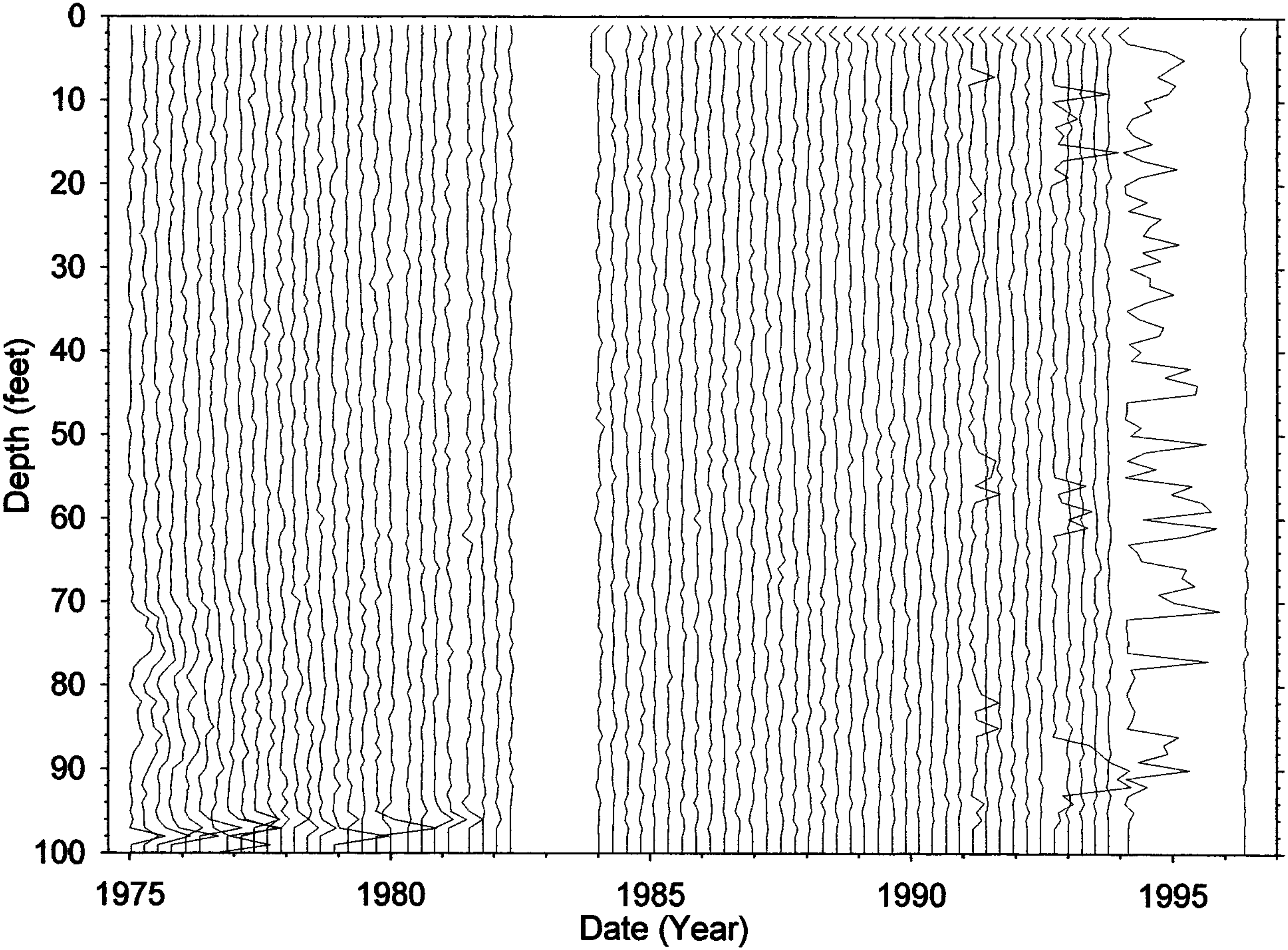
Number Surveys Rejected :	0	
Lower Threshold for Bad Survey Values :	<= 0	
Method Used to Compute Background :	Threshold 0<val<50, rest least squares fit	
Depth(s) where Contamination Identified in Gross Gamma Surveys :	70-90 UNSTABLE Early	
Analyst Name :	R.R. Randall	
Company Name :	Three Rivers Scientific	



HNF-3532 -REV0

00 278

Borehole 22-06-09



00 279

HNF-3532 -REV0

Borehole 22-06-11

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity

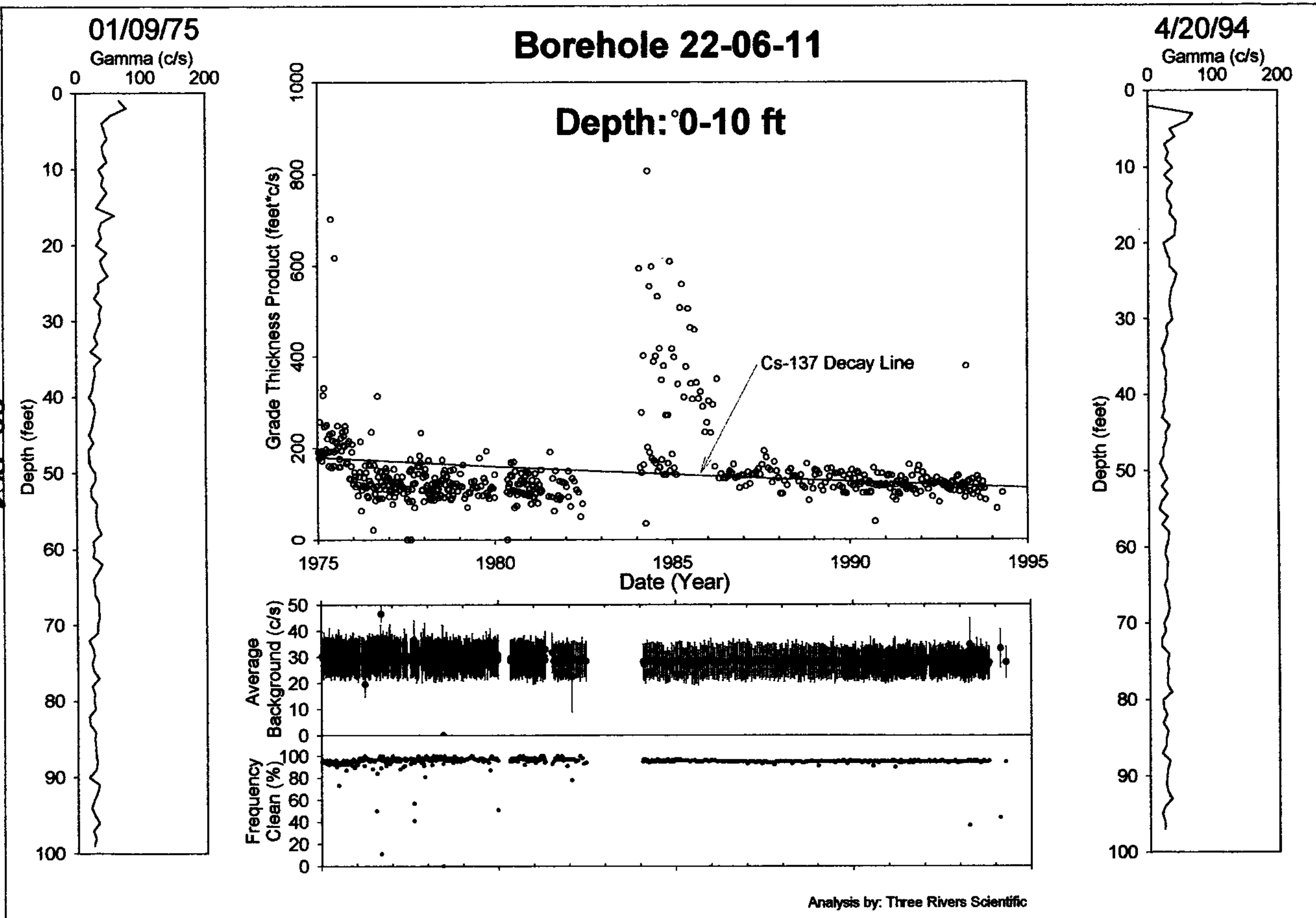
Grade Thickness Product from 0 to 10 feet is erratic from 1975 through 1986, and is categorized as Tank Farm activity. Grade Thickness Product from 1986 through 1994 is decreasing within counting statistics at a rate consistent with Cs-137 (identified from HPGe detector).

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (4 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	4/20/1994
Number Surveys :	543

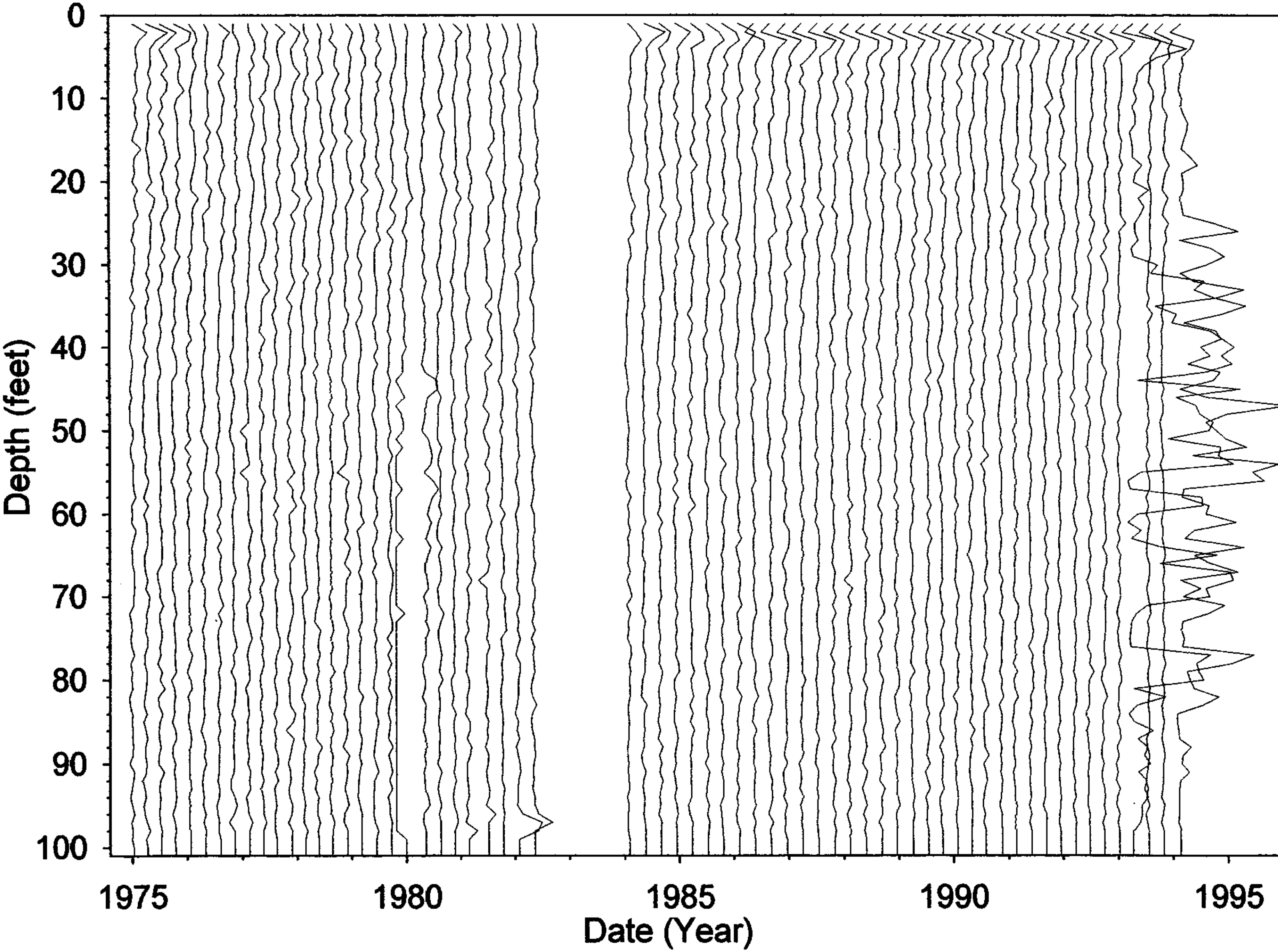
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	Threshold (0< val < 50)
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 feet is TF Activity
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific


01/09/75
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
Borehole 22-06-11
Depth: 0-10 ft
Grade Thickness Product (feet*c/s)
0 200 400 600 800 1000
Cs-137 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
4/20/94
Gamma (c/s)
0 100 200
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100

00 281

Borehole 22-06-11



HNF-3532 -REV0

Dry Well Survey Analysis - Notes

BY

Borehole 22-06-01 Total # Surveys 733 Probe Type 04 02

\# neutron surveys 6 # GR Surveys 726

Log Date: 1-9-75 1st 4-20-94 Last Presentation Plot Dates ______ (If different from 1st & Last)

Contamination Zone Depth(s): ______

Isotope from Spectral Survey: Cs (low) Co low Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			Peak @ 47 & 60 rapid decay
			random surface

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Prom Stack 42-52 52-65 0-8

Analyst Name Rick Randall S/W ver TFGRDSF 2.2

filein := "two52-65.txt" **Well 21-06-01**

$A := READPRN(filein)$ $yr := A^{\langle 1 \rangle}$ $net := A^{\langle 7 \rangle}$ $bkg := A^{\langle 6 \rangle}$ $max := A^{\langle 4 \rangle}$

$N := last(yr)$ $N = 698$ $i := 0..N$ $k := 0..300$ $j := 0..299$ $\tau eu := 1$

$\tau co := 5.27$ $\tau cs := 3 \cdot 10^9$ $aco := 300$ $acs := 0$

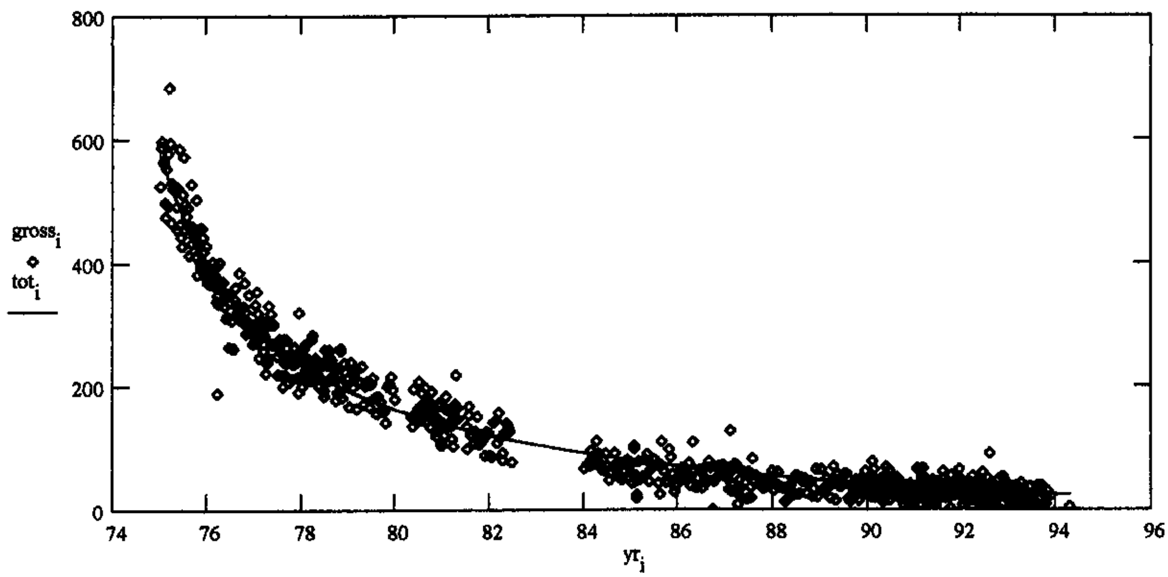
Eu variables are Ru-106 $aeu := 281$

$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1$ $tot_i := Co_i + Eu_i$

$gross_i := net_i$

Cs variables are U238

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

$ssq(aco, aeu) = 0$ $1 = 1$

$$\begin{bmatrix} \alpha co \\ \alpha eu \end{bmatrix} := Minerr(aco, aeu)$$

$\alpha co = 300.405$ Co-60 $\alpha eu = 281.326$ Ru-106

$\frac{\alpha co}{\alpha eu} = 1.068$

$Cs_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $tot_i := Co_i + Eu_i$

$out^{\langle 0 \rangle} := yr$ $out^{\langle 1 \rangle} := tot$ WRITEPRN("twop52-65.txt") := out $\frac{Eu_N}{Co_N} = 1.837 \cdot 10^{-5}$

Dry Well Survey Analysis - Notes

BY

Borehole 22-06-06 Total # Surveys 724 Probe Type 04 02

\# neutron surveys 5 # GR Surveys 718

Log Date: 1-16-75 1st 4-20-94 Last Presentation Plot Dates ____

(If different from 1st & Last)

Contamination Zone Depth(s): ____

Isotope from Spectral Survey: Cs & Co (high) Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			move down & statTyp? surface erratic

BackGnd.Txt

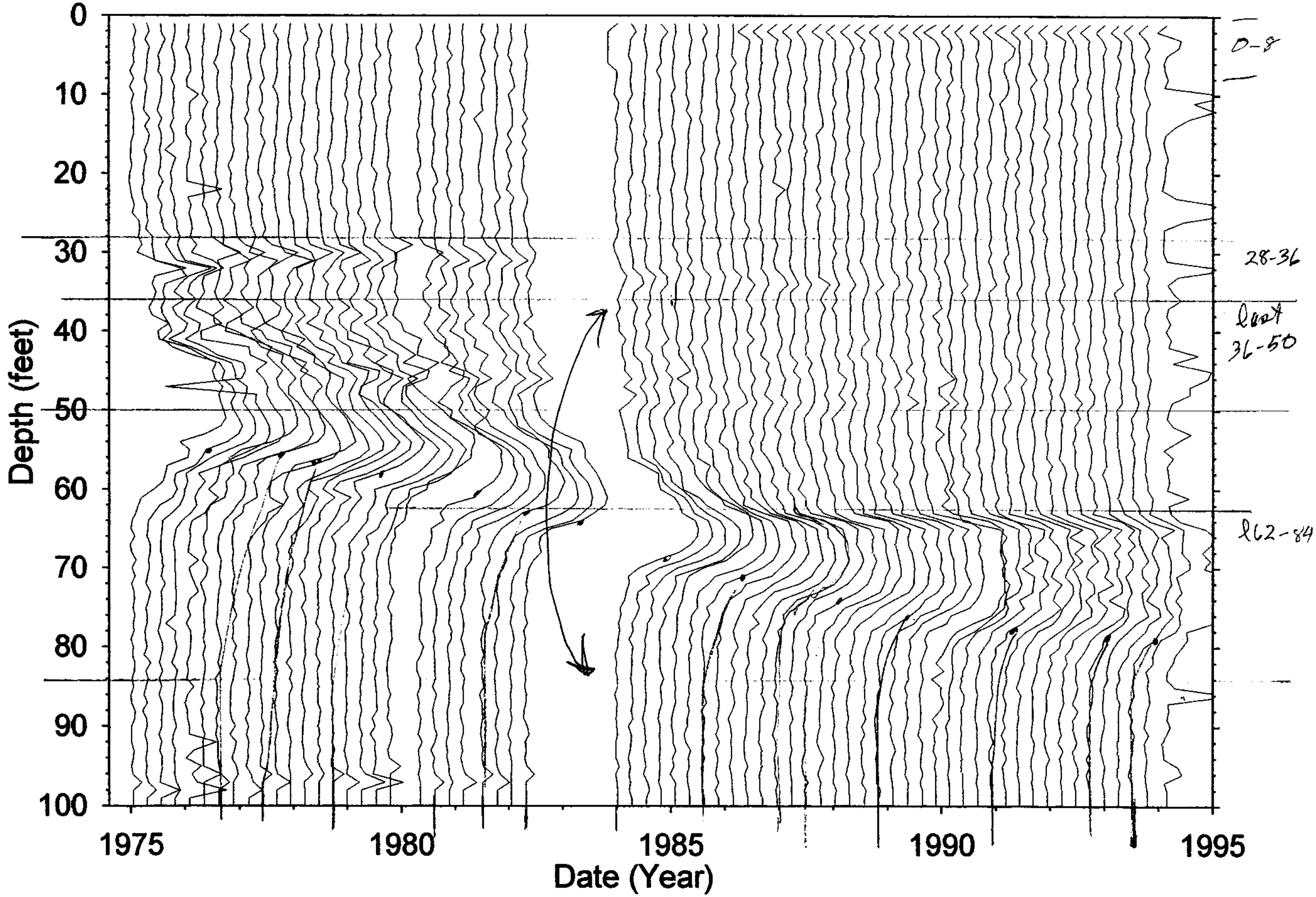
Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Down movement & top ranges up after 86 & continue to broaden

Analyst Name Russ Randall S/W ver TPGROSS 2.2

Borehole 22-06-05



00 286

filein := "two36-50.txt" **Well 21-06-05**

A := READPRN(filein) $yr := A^{\langle 1 \rangle}$ $net := A^{\langle 7 \rangle}$ $bkg := A^{\langle 6 \rangle}$ $max := A^{\langle 4 \rangle}$ B := 0

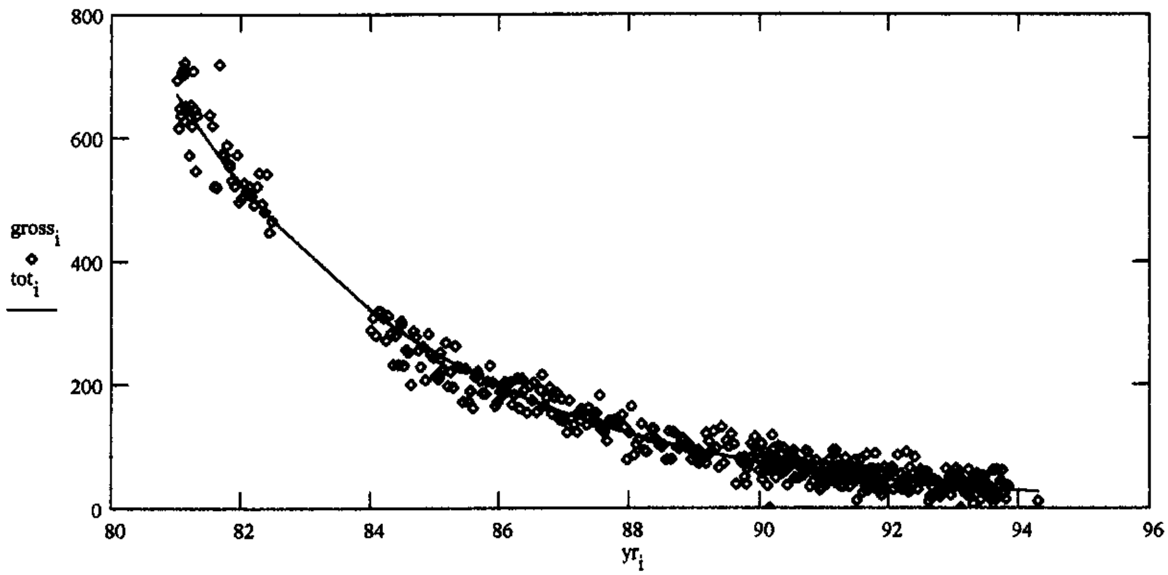
N := last(yr) N = 442 i := 0 .. N k := 0 .. 300 j := 0 .. 299 $\tau eu := 2.77$

$\tau co := 5.27$ $\tau cs := 30.17$ aco := 42 acs := 0 Eu variables are Sb-125 aeu := 2940

$Cs_i := acs \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau eu}} \cdot 1$ $tot_i := Co_i + Eu_i$

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau co}} + a3 \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

ssq(aco, aeu) = 0 1 = 1

$\begin{bmatrix} \alpha co \\ \alpha eu \end{bmatrix} :=$ Minerr(aco, aeu)

$\alpha co = 42$ Co-60 $\alpha eu = 2.94 \cdot 10^3$ Sb-125

$yr_i := 75 + \frac{i}{N} \cdot 20$

$\frac{\alpha co}{\alpha eu} = 0.014$

$Co_i := \alpha co \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau co}}$ $Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\frac{\ln(2)}{\tau eu}}$ $tot_i := Co_i + Eu_i$

$out^{\langle 0 \rangle} := yr$ $out^{\langle 1 \rangle} := tot$ WRITEPRN("twop36-50.txt") := out $\frac{Eu_N}{Co_N} = 6.517$

filein := "two28-36.txt" **Well 21-06-05**

$A := \mathrm{READPRN}(filein)$ $yr := A^{\langle 1 \rangle}$ $net := A^{\langle 7 \rangle}$ $bkg := A^{\langle 6 \rangle}$ $max := A^{\langle 4 \rangle}$ $B := 0$

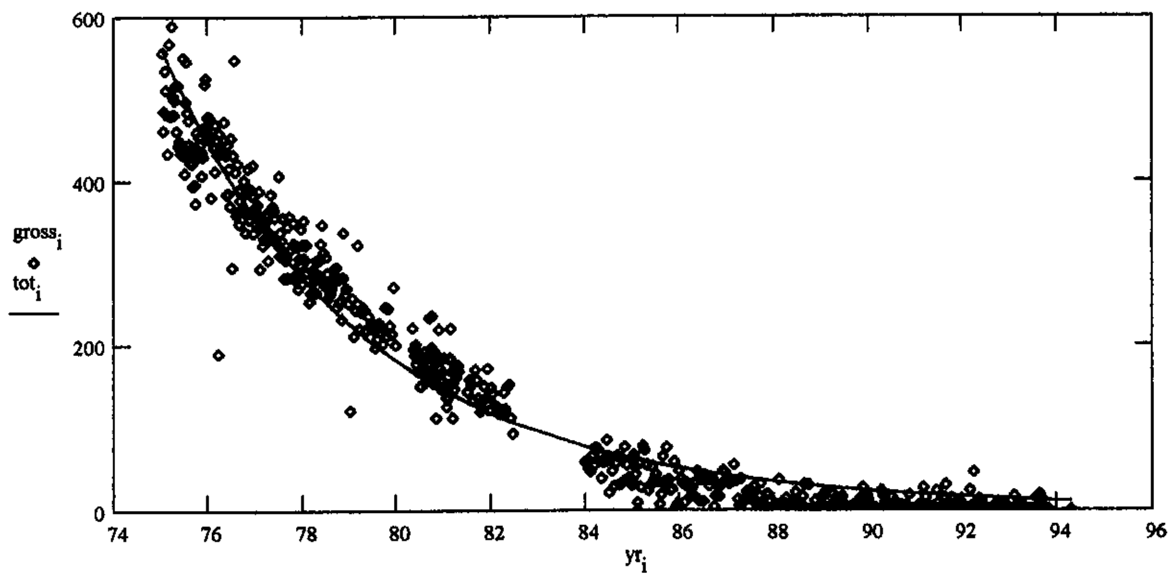
$N := \mathrm{last}(yr)$ $N = 704$ $i := 0..N$ $k := 0..300$ $j := 0..299$ $\tau eu := 2.77$

$\tau co := 5.27$ $\tau cs := 30.17$ $aco := 89$ $acs := 0$ Eu variables are Sb-125 $aeu := 477$

$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1$ $tot_i := Co_i + Eu_i$

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

$ssq(aco, aeu) = 0$ $1 = 1$

$\begin{bmatrix} \alpha co \\ \alpha eu \end{bmatrix} := \mathrm{Minerr}(aco, aeu)$

$\alpha co = 89$ Co-60 $\alpha eu = 477$ Sb-125

$Cs_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $tot_i := Co_i + Eu_i$ $\frac{\alpha co}{\alpha eu} = 0.187$

$out^{\langle 0 \rangle} := yr$ $out^{\langle 1 \rangle} := tot$ WRITEPRN("twop28-36.txt") := out $\frac{Eu_N}{Co_N} = 0.542$

BY

Dry Well Survey Analysis - Notes

Borehole 22-06-07 Total # Surveys 540 Probe Type 04 02
neutron surveys 4 # GR Surveys 535
Log Date: 1-9-75 1st 4-20-94 Last Presentation Plot Dates
(If different from 1st & Last)

Contamination Zone Depth(s):
Isotope from Spectral Survey: Cs & Co Max Survey Depth 140 130

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			0-8 40-52 52-80
			HZ shows increase ↑

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Analyst Name [signature: Russell Randall] S/W ver TFGROSS 2.2

Dry Well Survey Analysis - Notes

Borehole 22-06-09 Total # Surveys 715 Probe Type 04 02

\# neutron surveys 5 # GR Surveys 709

Log Date: 1-9-75 1st 5-23-96 Last Presentation Plot Dates ______ (If different from 1st & Last)

Contamination Zone Depth(s): ______

Isotope from Spectral Survey: Cs low Co low Max Survey Depth 100

GAPS.Txt

Survey Date	num. Gaps	num. Samples	Comment

HI-ZONES.Txt

Survey Date	Reason Selected	num. Samples	Comment
			[illegible] doublet @ 80' rapid decay
			stack

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq.Clean	Avg.Bkg	Comment

Analysis Notes

Analyst Name Roger Randall S/W ver TFGR0552-2

filein := "two70-90.txt" **Well 21-06-09**

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

N := last(yr) N = 649 i := 0 .. N k := 0 .. 300 j := 0 .. 299 $\tau eu := 1$

$\tau co := 5.27$ $\tau cs := 3\cdot 10^{9}$ BKG aco := 00 acs := 43

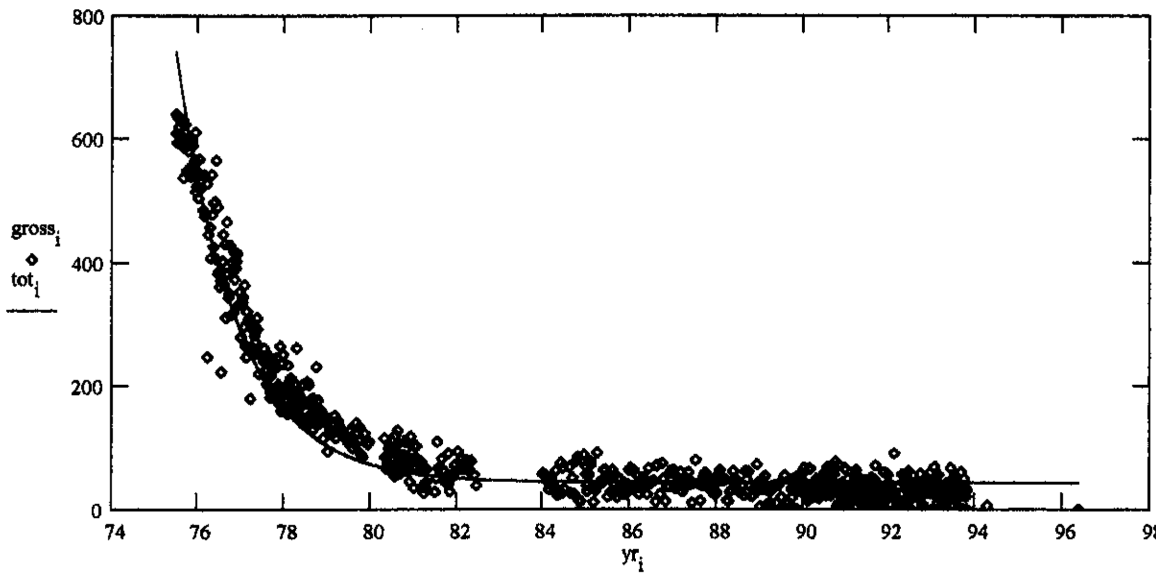
Eu variables are Ru-106 aeu := 986

$Cs_i := acs\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}\cdot 1$ $tot_i := Cs_i + Eu_i$

$gross_i := net_i$

Cs variables are U238

This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \right] \right]^2$$

Given

ssq(acs, aeu) = 0 1 = 1

$$\begin{bmatrix} \alpha cs \\ \alpha eu \end{bmatrix} := Minerr(acs, aeu)$$

$\alpha cs = 43.037$ Background $\alpha eu = 982.617$ Ru-106

$\frac{\alpha cs}{\alpha eu} = 0.044$

$Cs_i := \alpha cs\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $tot_i := Cs_i + Eu_i$

$\frac{Eu_N}{Cs_N} = 8.28\cdot 10^{-6}$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop.txt") := out

Dry Well Survey Analysis - Notes

Borehole BY/22-06-11) Total # Surveys 548 Probe Type 04
\# neutron surveys 4 # GR Surveys 543
Log Date: 75-01-09 1st 94-04-20 Last Presentation Plot Dates ______
(If different from 1st & Last)
Isotope from Spectral Survey: Cs-137 (0-37FT) ≤10pCi/g Max Survey Depth 100
Contamination Zone Depth(s): 0-10FT

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-07-21	44	85	
76-07-29	12	90	
77-08-12	27	70	
79-12-27	46	95	
82-01-27	21	95	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-06-26	HI BKG	95	
76-09-09	HI BKG	95	
78-06-08	TOOL FAIL	100	
93-04-13	TOOL FAIL	100	
94-02-23	TOOL FAIL	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
76-07-21	%CLEAN	88	50%	28.9	
76-09-09	%CLEAN	97	11%	46.5	
77-08-12	%CLEAN	75	57%	36.6	
77-12-01	AVG BKG	98	81%	36.6	
78-06-08	AVG BKG	97	93%	35.4	
79-10-03	AVG BKG	98	87%	35.7	
93-04-13	%CLEAN	97	37%	34.8	
94-02-23	%CLEAN	97	44%	33.2	

Analysis Notes

num surveys rejected: (0) ZERO Background = (0<val<50)

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V2.20.

Borehole 22-07-01

Contamination (Cs-137) from 0 to 10 feet is Tank Farm Activity
Contamination (Cs-137) from 40-52 feet is UNSTABLE
Contamination (Co-60) from 52-70 feet is Stable
Contamination (Co-60) from 70-92 feet is Stable

Grade Thickness Product from 0 to 10 feet is erratic from 1975 to 1986, and is categorized as Tank Farm activity. Then from 1986 to 1995 the Grade Thickness Product is decreasing within counting statistics at a rate consistent with Cs-137 (identified from HPGe detector).

Grade Thickness Product for radioactive zone (40-52 feet) shows a consistent INCREASE from 1975 to mid-year 1976, then from 1976 to 1979 a decrease is shown that is not consistent with the decay rate of Cs-137 (identified from HPGe detector). The contaminant responsible for much of the gross gamma may be other than Cs-137, but moved out laterally, since the lower zones are stable. After 1986 the Grade Thickness Product is essentially at background activity.

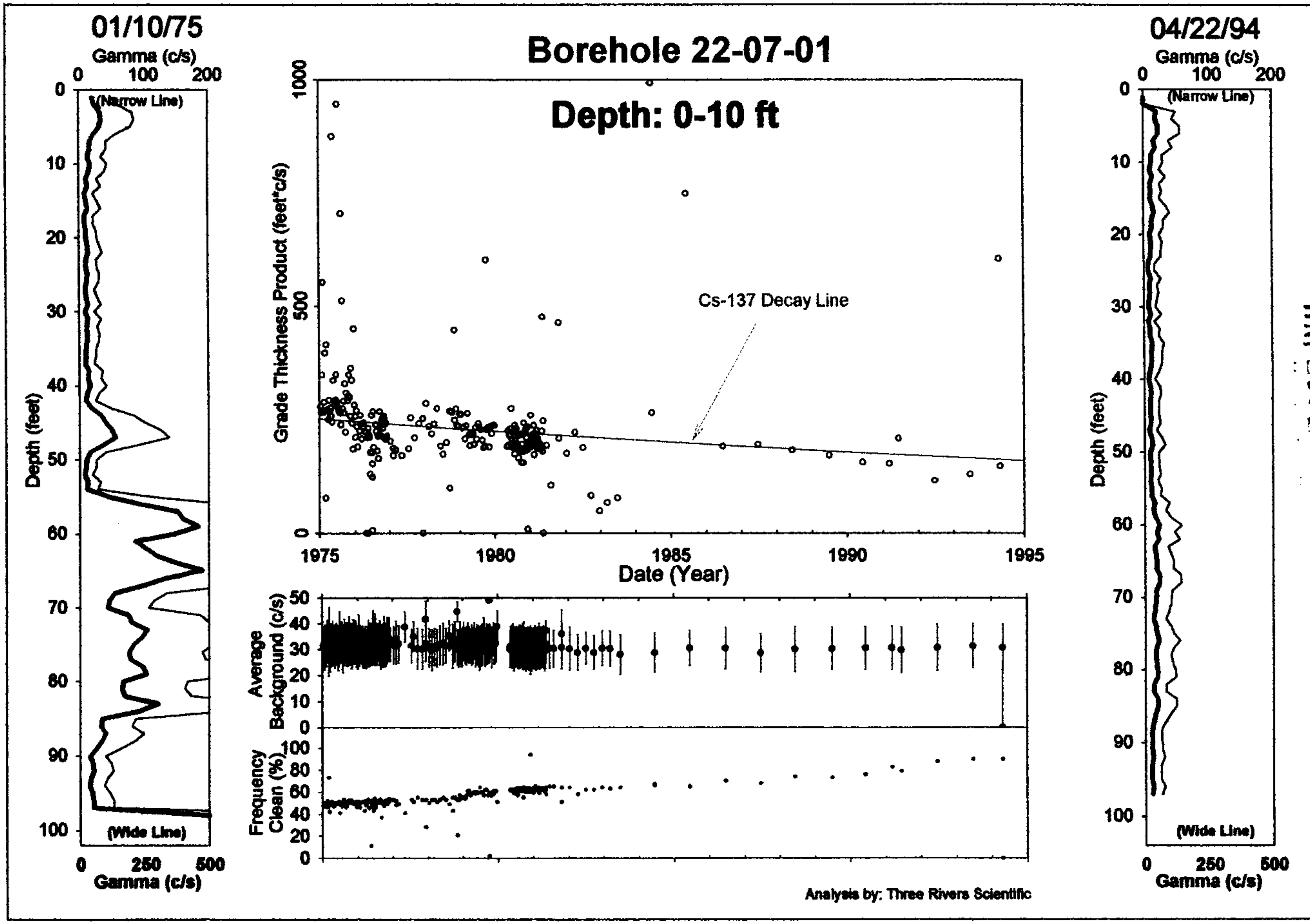
Grade Thickness Product for the two radioactive zones (52-70 and 70-92 feet) is decreasing within the gross gamma sensitivity at a rate consistent with the decay of Co-60 (identified from HPGe detector) between 1975 and 1994.

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (7 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	4/22/1994
Number Surveys :	242

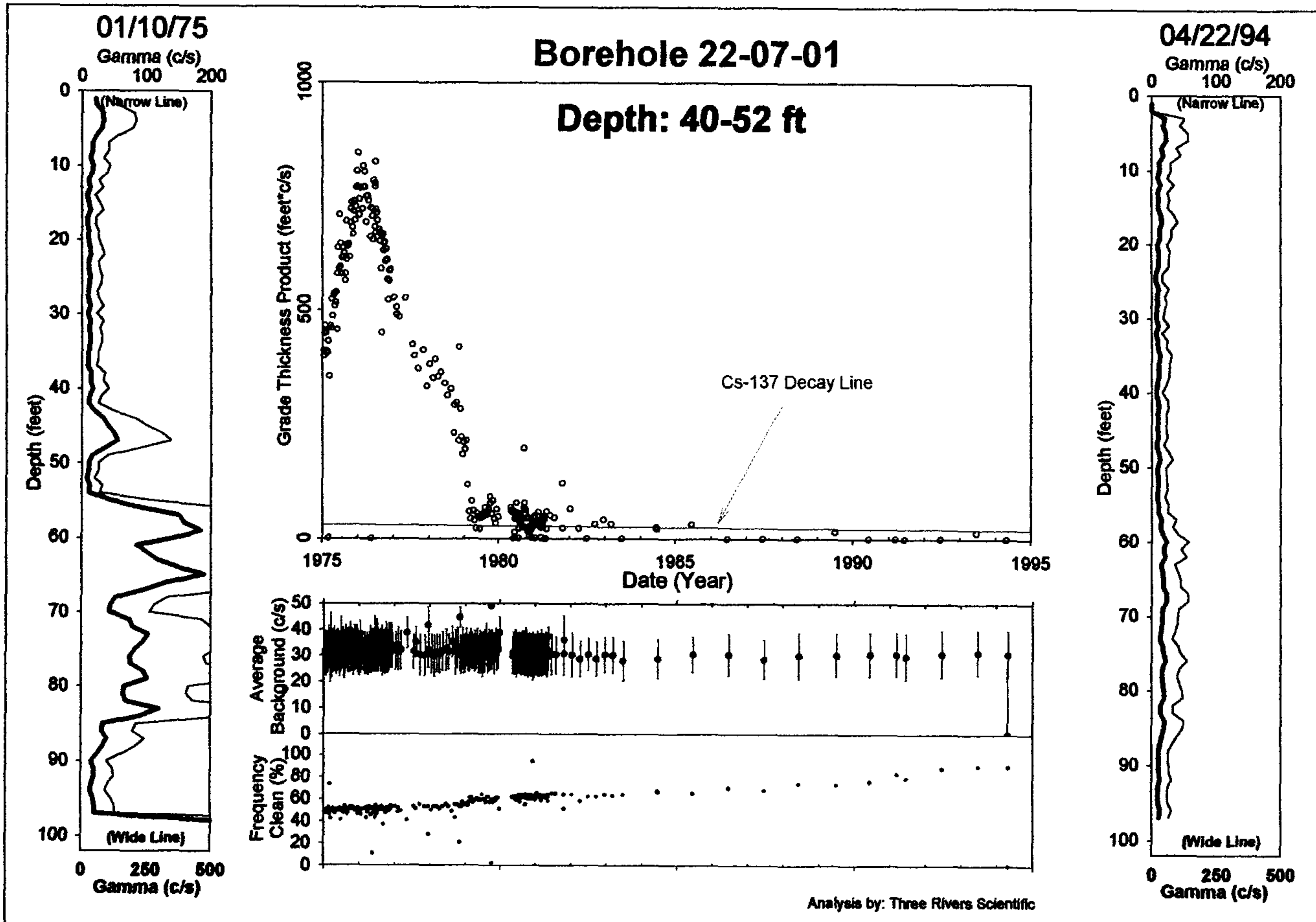
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	10 to 40 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 feet is TF Activity 40-51 feet was UNSTABLE 52-70, 70-92 feet is Stable
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



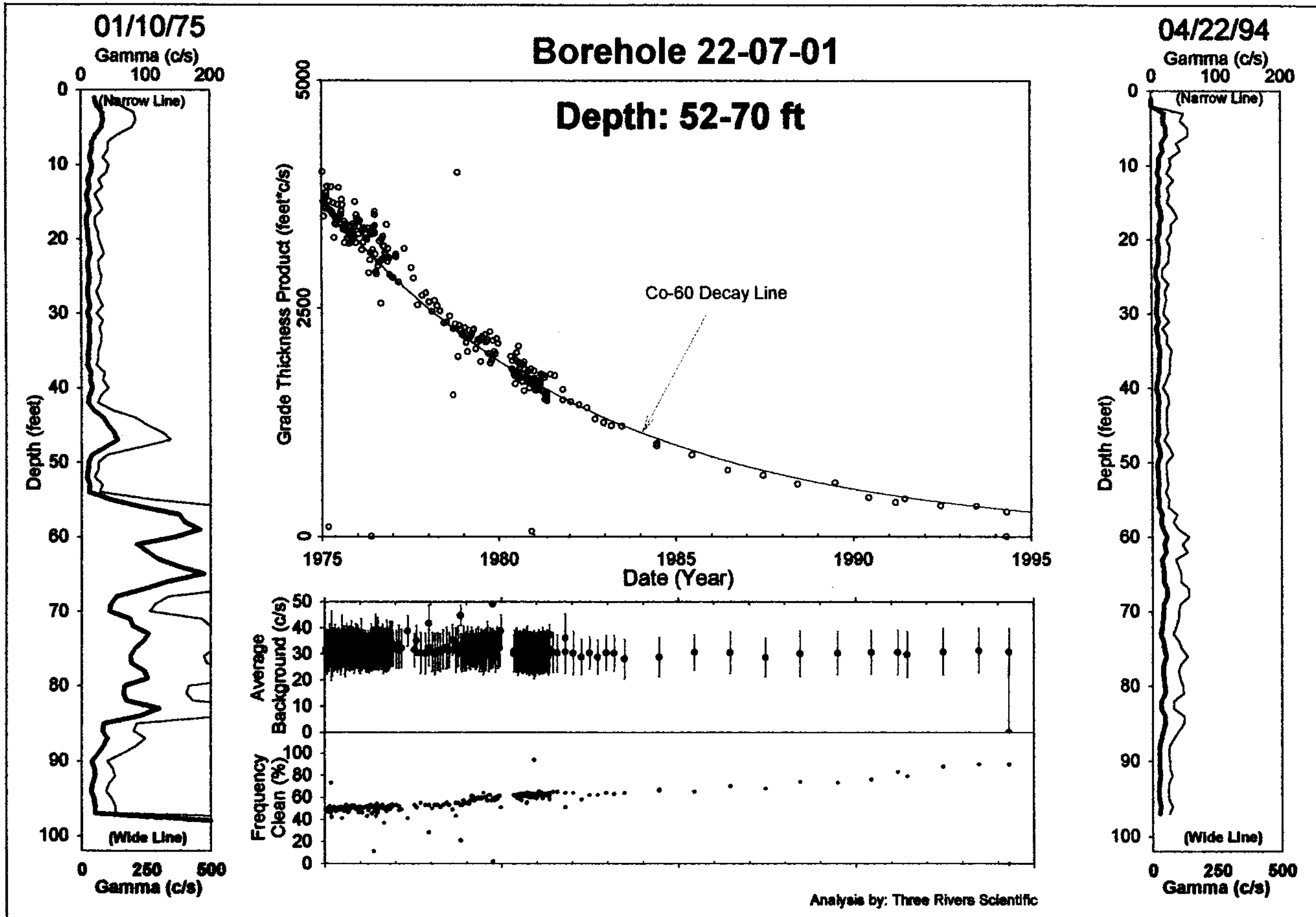
HNF-3532-REV0

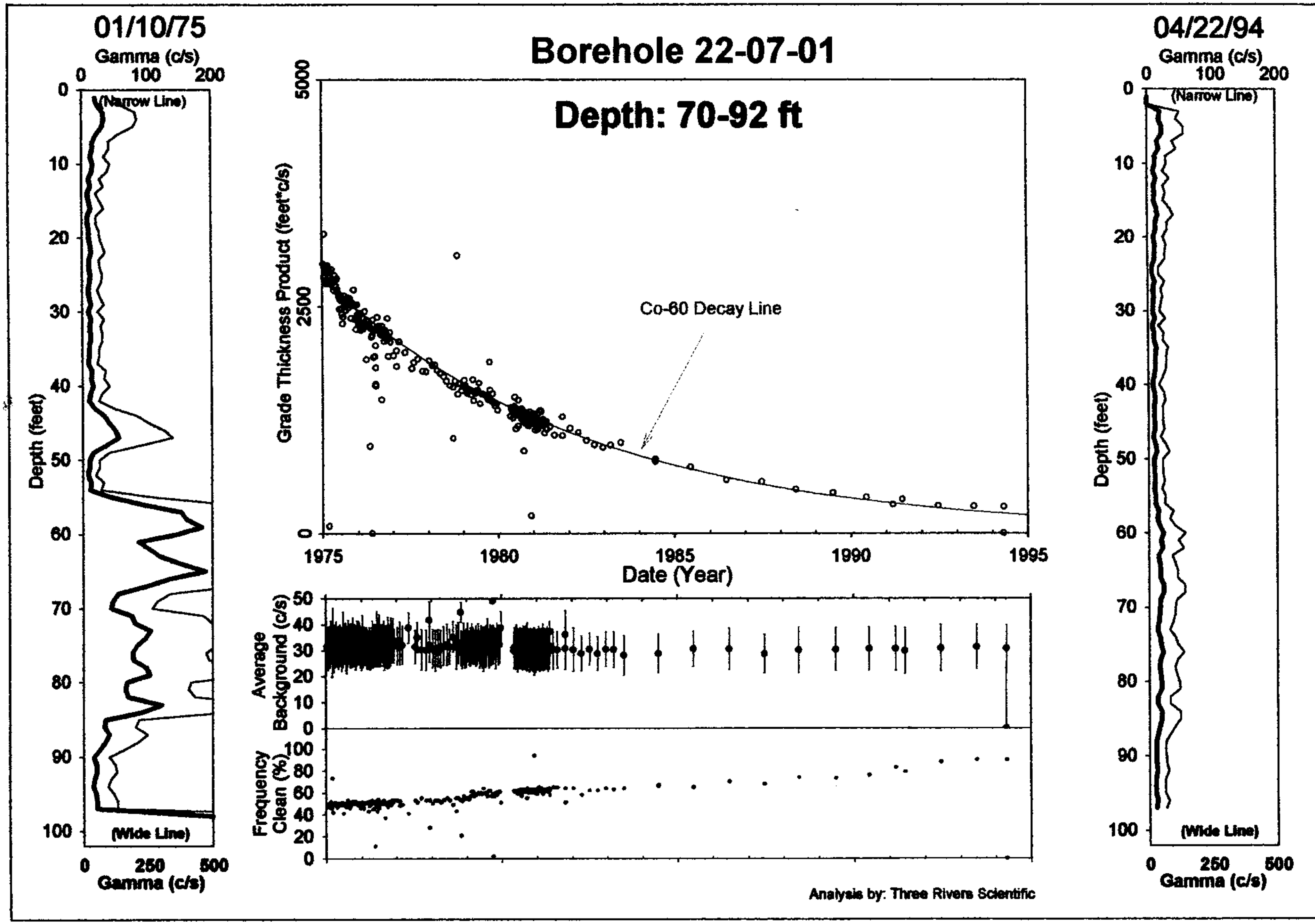
00 294



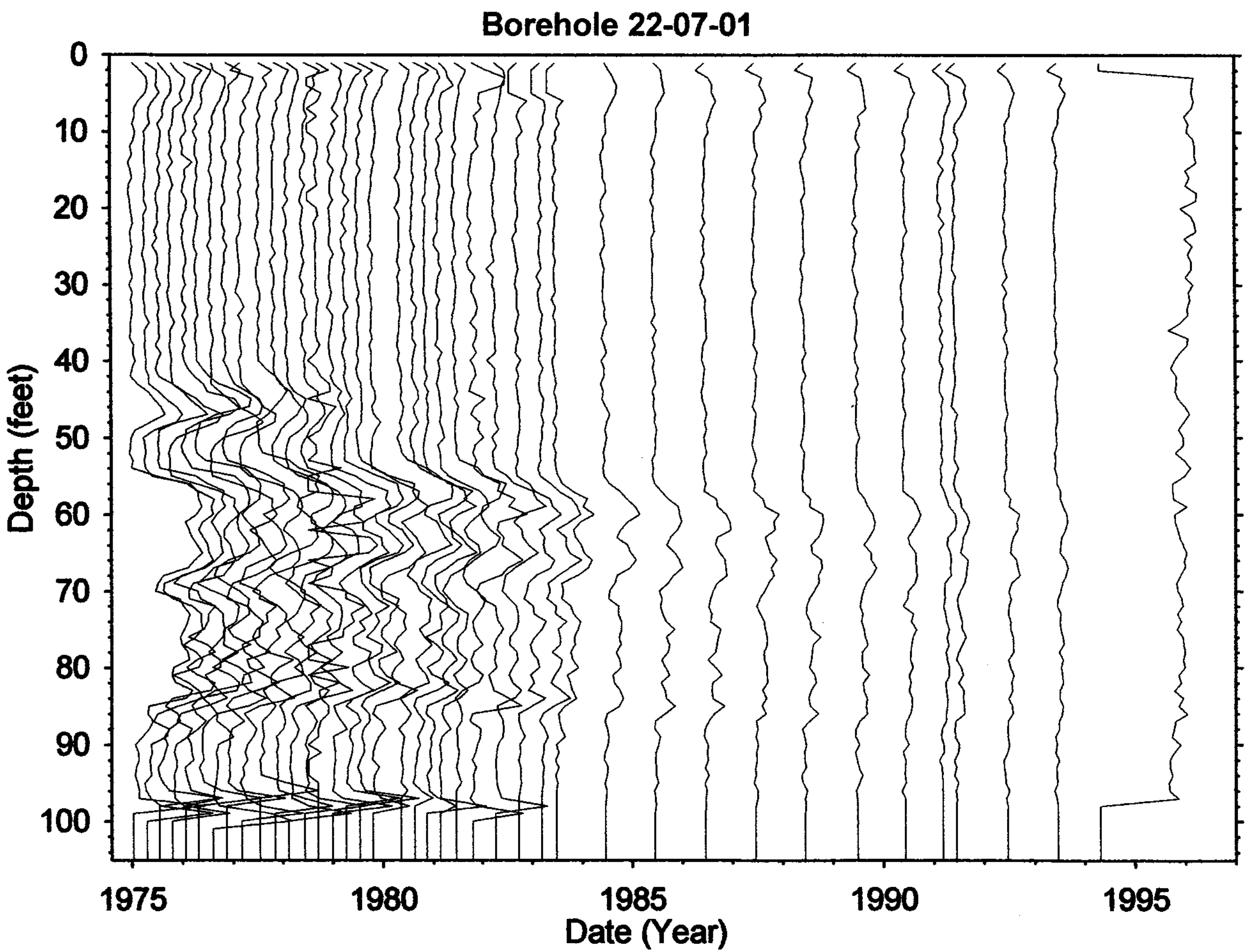
HNF-3532 -REV0

00 295


01/10/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Borehole 22-07-01
Depth: 52-70 ft
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
04/22/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)



HNF-3532 - REV0



HNF-3532 -REV0

00 298

Borehole 22-07-02

Contamination (Cs-137) from 6 to 20 feet is Appears Stable
Contamination (Co-60) from 42-53 feet is **UNSTABLE**
Contamination (Co-60) from 53-70 feet is **UNSTABLE**
Contamination (Co-60) from 70-82 feet is **UNSTABLE**
Contamination (Co-60) from 82-95 feet is **UNSTABLE**

Grade Thickness Product for the low level radioactive zone from 6 to 20 feet appears to be decreasing within counting statistics at a rate consistent with Cs-137 (identified from HPGe detector), except for 1976 when the Grade Thickness Product was below the decay line.

Grade Thickness Product for radioactive zone (42-53 feet) has a significant INCREASE in 1975, then from mid year 1975 to 1980 the rate of decrease is significantly greater than the decay rate of Co-60 (identified from HPGe detector). In 1980 a large step change in the Grade Thickness Product occurs. The Co-60 decay line is plotted to show the activity in the radioactive zone does not match the decay rate.

Grade Thickness Product for the radioactive zone (53-70 feet) is slowly INCREASING from 1975 to 1979, then in 1979 a large and rapid increase occurs, followed by a rapid decrease to 1983. The stack plot shows the rapid occurrence of a radioactive zone that coincides with the depletion of the radioactive zone from 42-53 feet. The decay line for Co-60 (identified from HPGe detector) is plotted but does not match the Grade Thickness Product.

Grade Thickness Product for the radioactive zone (70-82 feet) is decreasing within the gross gamma sensitivity at a rate consistent with the decay of Co-60 (identified from HPGe detector), except from 1980 to 1987. In 1980 an INCREASE in the Grade Thickness Product occurs, then from 1981 to 1987 the rate of decrease is much greater than the decay rate of Co-60.

Grade Thickness Product for the radioactive zone (82-95 feet) is decreasing within the gross gamma sensitivity at a rate consistent with the decay of Co-60 (identified from HPGe detector) during two time intervals (1978-1982 and 1987-1995). During the other times (1975-1978 and 1982-1987) an INCREASE followed by an extended period of accelerated decrease was recorded.

Borehole 22-07-02

page 2 of 2

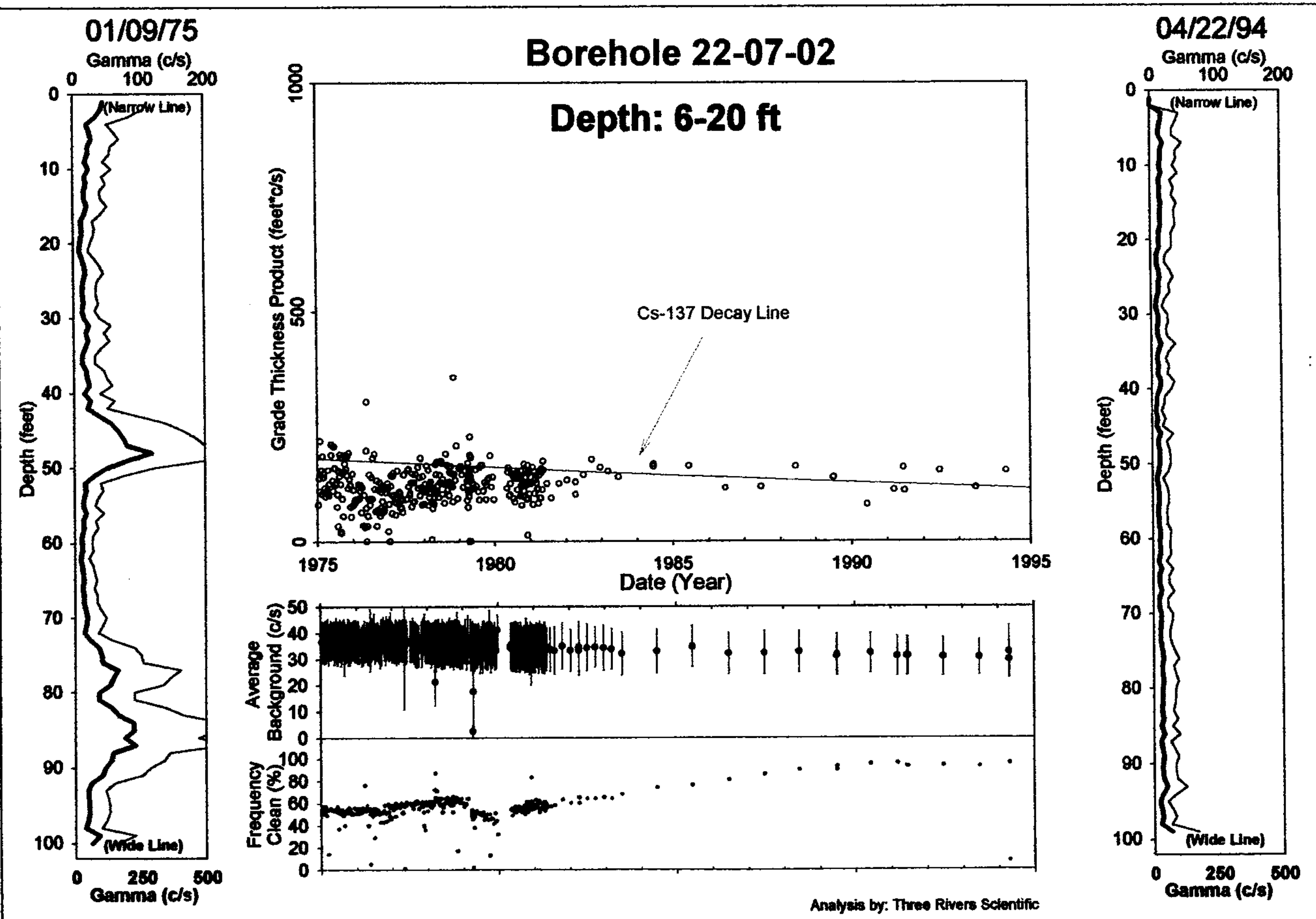
Grade Thickness Product for the combined radioactive zone (42-95 feet) has two periods of rapid INCREASE (1975 and 1979) followed by two periods of accelerated decrease (1976-1979 and 1980-1987), indicating that two releases of radioactive materials occurred.

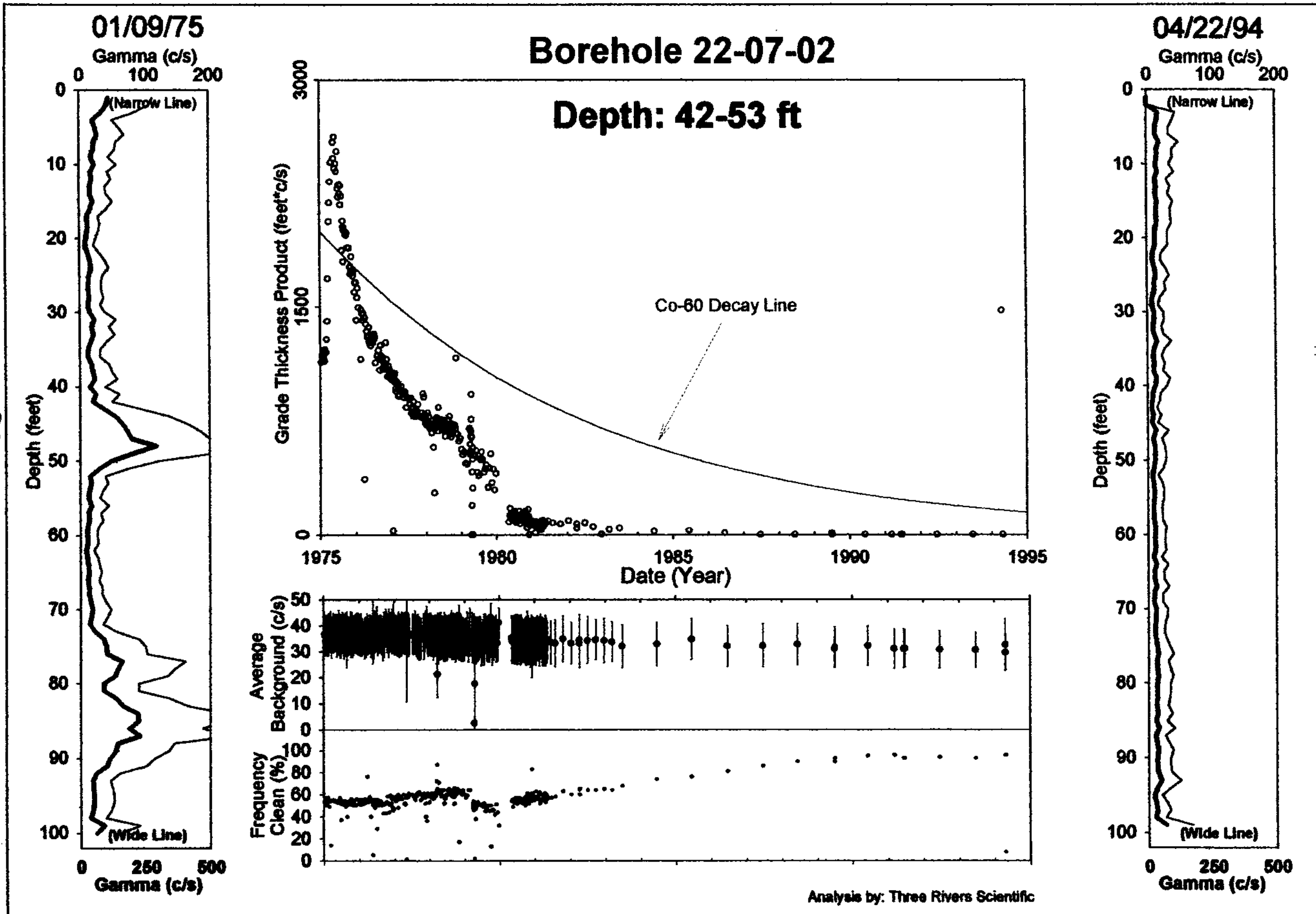
Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (6 surveys)
Borehole Depth :	97 ft
Survey Depth :	97 ft
First Survey Date :	1/09/1975
Last Survey Date :	4/22/1994
Number Surveys :	336

Analysis Notes

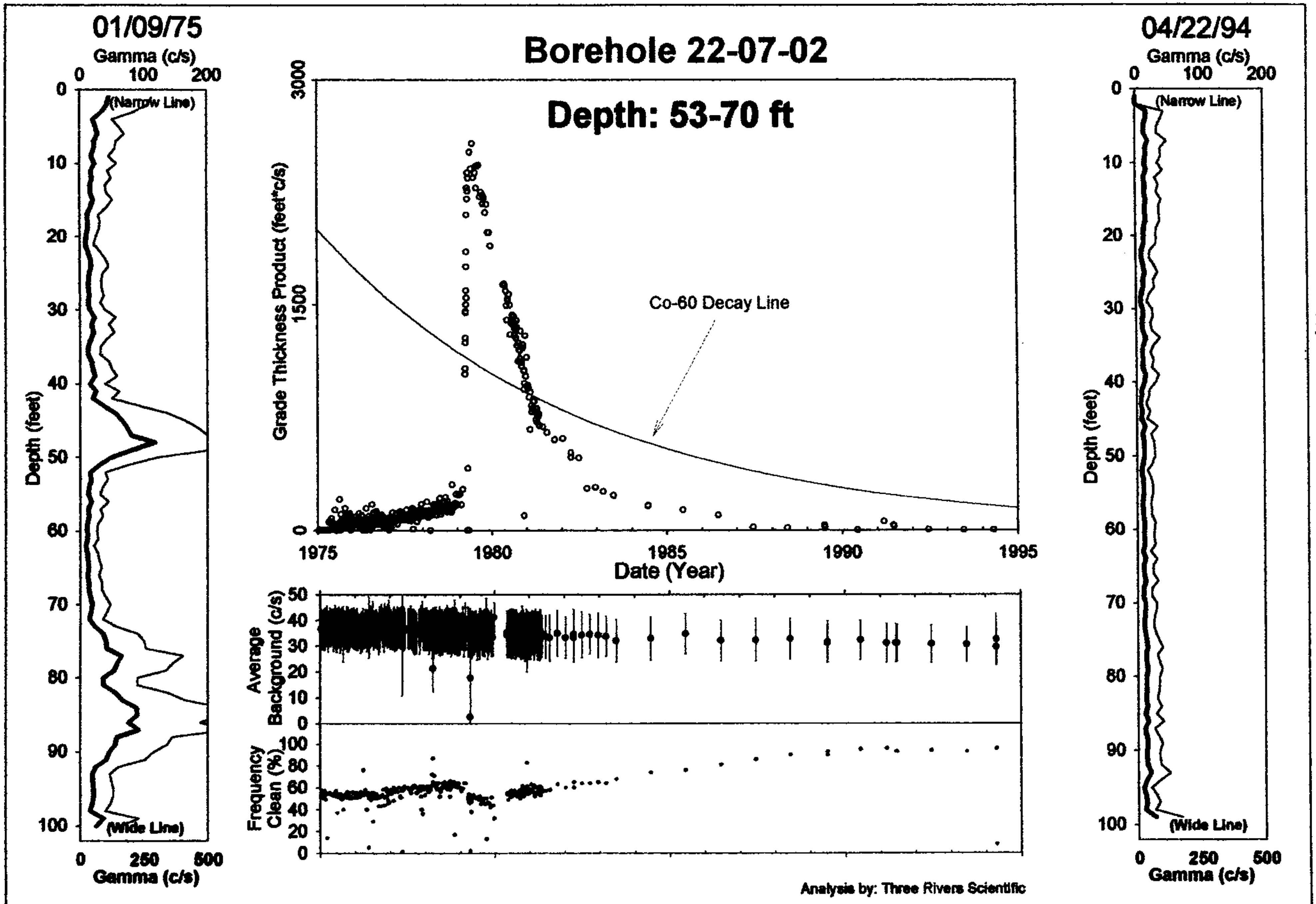
Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	20 to 40 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	6-20 feet is appears Stable 42-53, 53-70, 70-82, 82-95 feet is UNSTABLE
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific


Borehole 22-07-02
Depth: 6-20 ft
01/09/75
Gamma (c/s)
0 100 200
(Narrow Line)
(Wide Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
0 250 500
Gamma (c/s)
Grade Thickness Product (feet*c/s)
0 500 1000
Cs-137 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
04/22/94
Gamma (c/s)
0 100 200
(Narrow Line)
(Wide Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
0 250 500
Gamma (c/s)



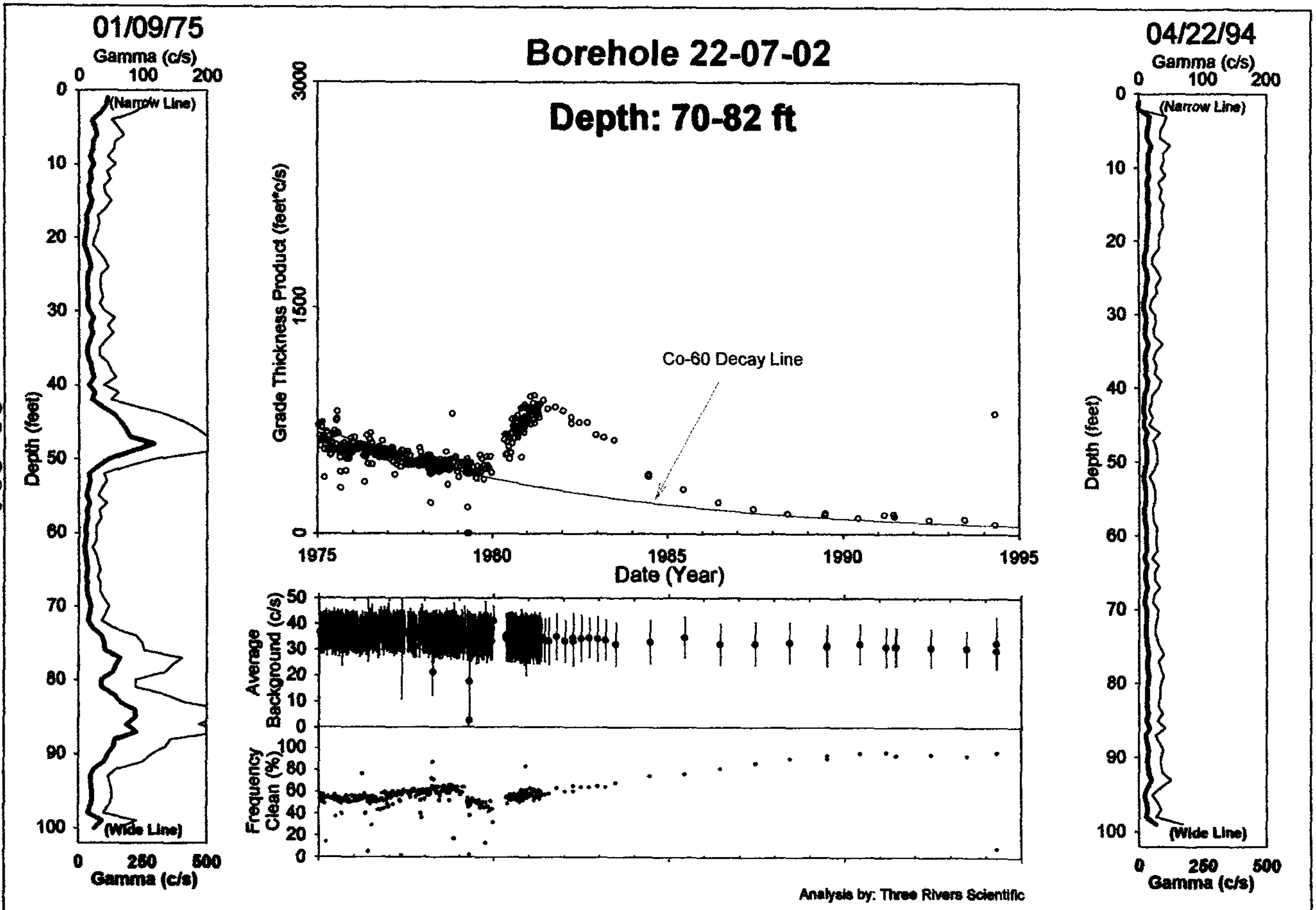
01/09/75
Gamma (c/s)
0
100
200
(Narrow Line)
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
(Wide Line)
0
250
500
Gamma (c/s)
Borehole 22-07-02
Depth: 42-53 ft
Grade Thickness Product (feet*c/s)
0
1500
3000
Co-60 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average Background (c/s)
0
10
20
30
40
50
Frequency Clean (%)
0
20
40
60
80
100
Analysis by: Three Rivers Scientific
04/22/94
Gamma (c/s)
0
100
200
(Narrow Line)
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
(Wide Line)
0
250
500
Gamma (c/s)

00 302

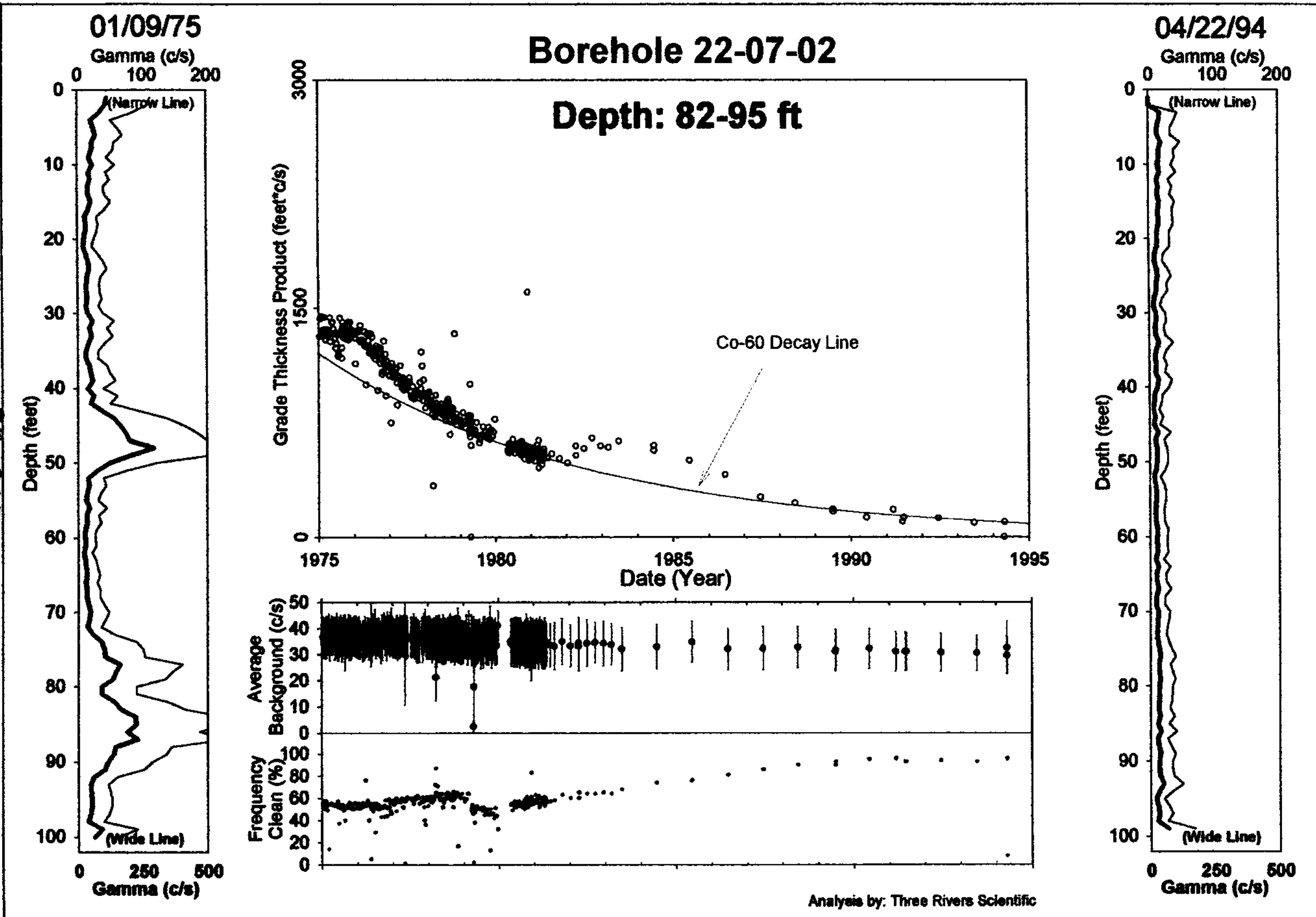


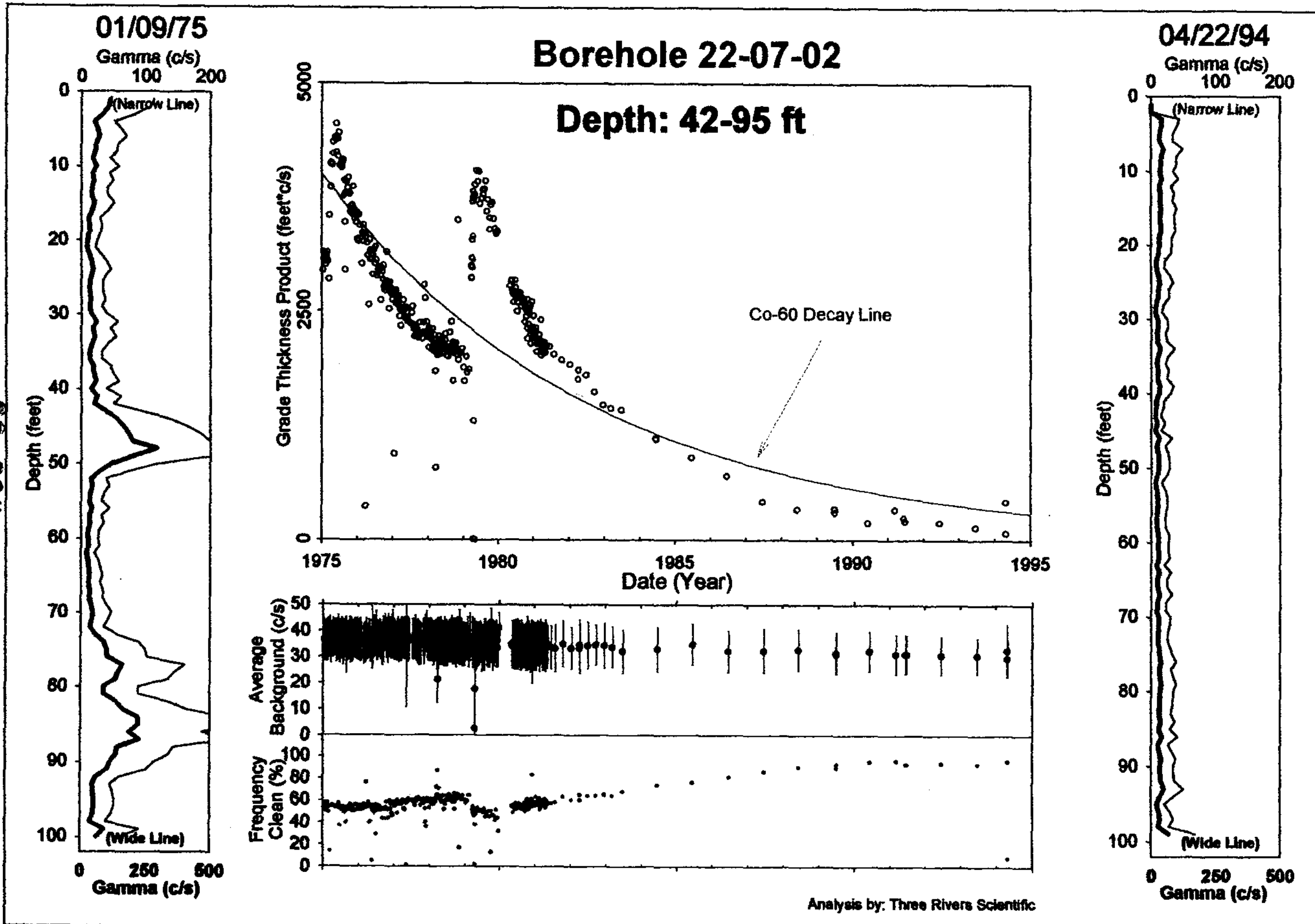
01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Borehole 22-07-02
Depth: 53-70 ft
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
04/22/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)

00 303


01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Borehole 22-07-02
Depth: 70-82 ft
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
04/22/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)

00 304

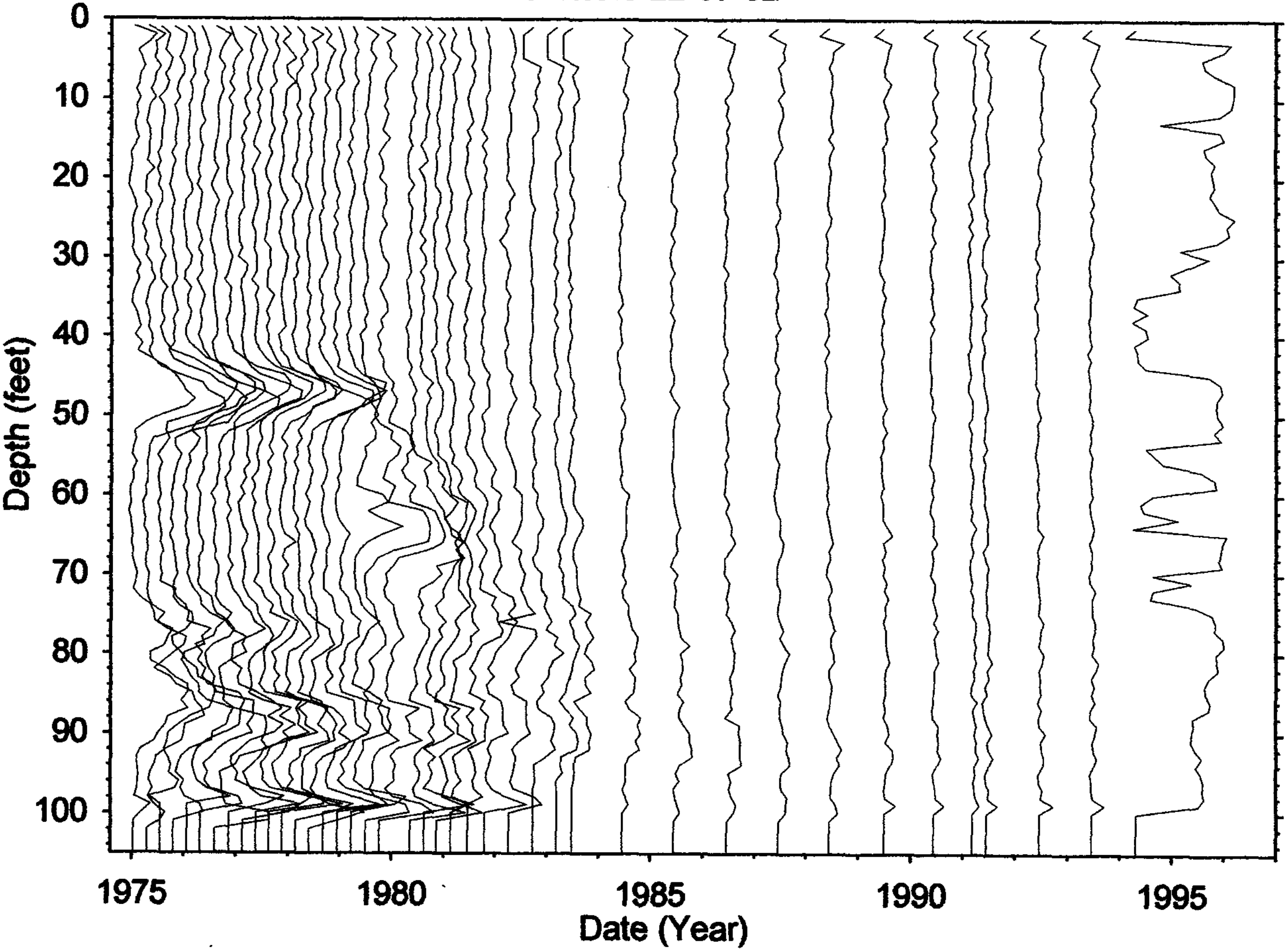

01/09/75
Gamma (c/s)
0 100 200
(Narrow Line)
(Wide Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
0 250 500
Gamma (c/s)
Borehole 22-07-02
Depth: 82-95 ft
Grade Thickness Product (feet*c/s)
0 1500 3000
Co-60 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
04/22/94
Gamma (c/s)
0 100 200
(Narrow Line)
(Wide Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
0 250 500
Gamma (c/s)



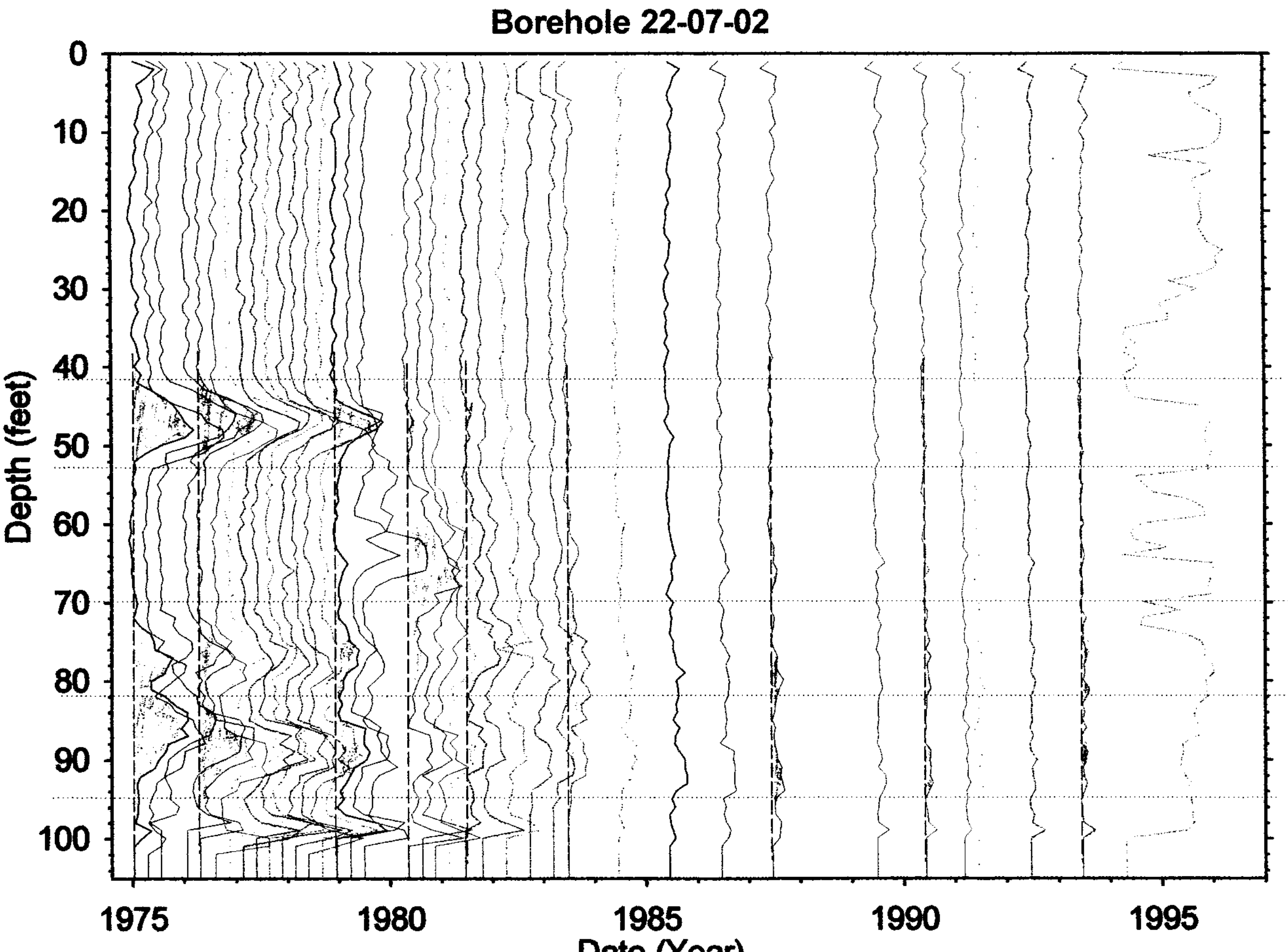
HNF-3532 -REV0

00 306

Borehole 22-07-02



HNF-3532 -REV0



00 308

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Borehole 22-07-05

page 1 of 2

Contamination (Co-60) from 40-57 feet is **UNSTABLE**
Contamination (Co-60) from 57-65 feet is **UNSTABLE**
Contamination (Co-60) from 65-78 feet is **UNSTABLE**
Contamination (Co-60) from 90-100 feet is Undetermined

Grade Thickness Product for radioactive zone (40-57 feet) is decreasing at a rate that is much greater than the decay rate of Co-60 (identified from HPGe detector) from 1975 to 1983. The Co-60 decay line is plotted to show the activity in the radioactive zone does not match the decay rate.

Grade Thickness Product for the radioactive zone (57-65 feet) is decreasing within observed systematic limitations at a rate consistent with the decay of Co-60 (identified from HPGe detector) during two time intervals (1975-1979 and 1986-1995). However, from 1979 to 1986 an INCREASE followed by an elevated decrease in the Grade Thickness Product occurred. The stack plot shows the migration of contamination down through this zone.

Grade Thickness Product for the radioactive zone (65-78 feet) is decreasing within observed systematic limitations at a rate consistent with the decay of Co-60 (identified from HPGe detector) during two time intervals (1975-1982 and 1988-1995). However, from 1982 to 1988 an INCREASE in the Grade Thickness Product occurred.

Grade Thickness Product for the radioactive zone (90-100 feet) is erratic from 1975 to 1985. Surveillance logging activities were not designed to monitor low contamination levels near the surface or bottom of the borehole. Grade Thickness Product from 1985 through 1994 is decreasing within counting statistics at a rate consistent with Cs-137 (identified from HPGe detector).

Grade Thickness Product for the combined radioactive zone (40-78 feet) is decreasing within observed systematic limitations at a rate consistent with the decay of Co-60 (identified from HPGe detector) between 1975 and 1994, indicating that no additions to the radioactive materials occurred while the contaminants were migrating through the vadose zone.

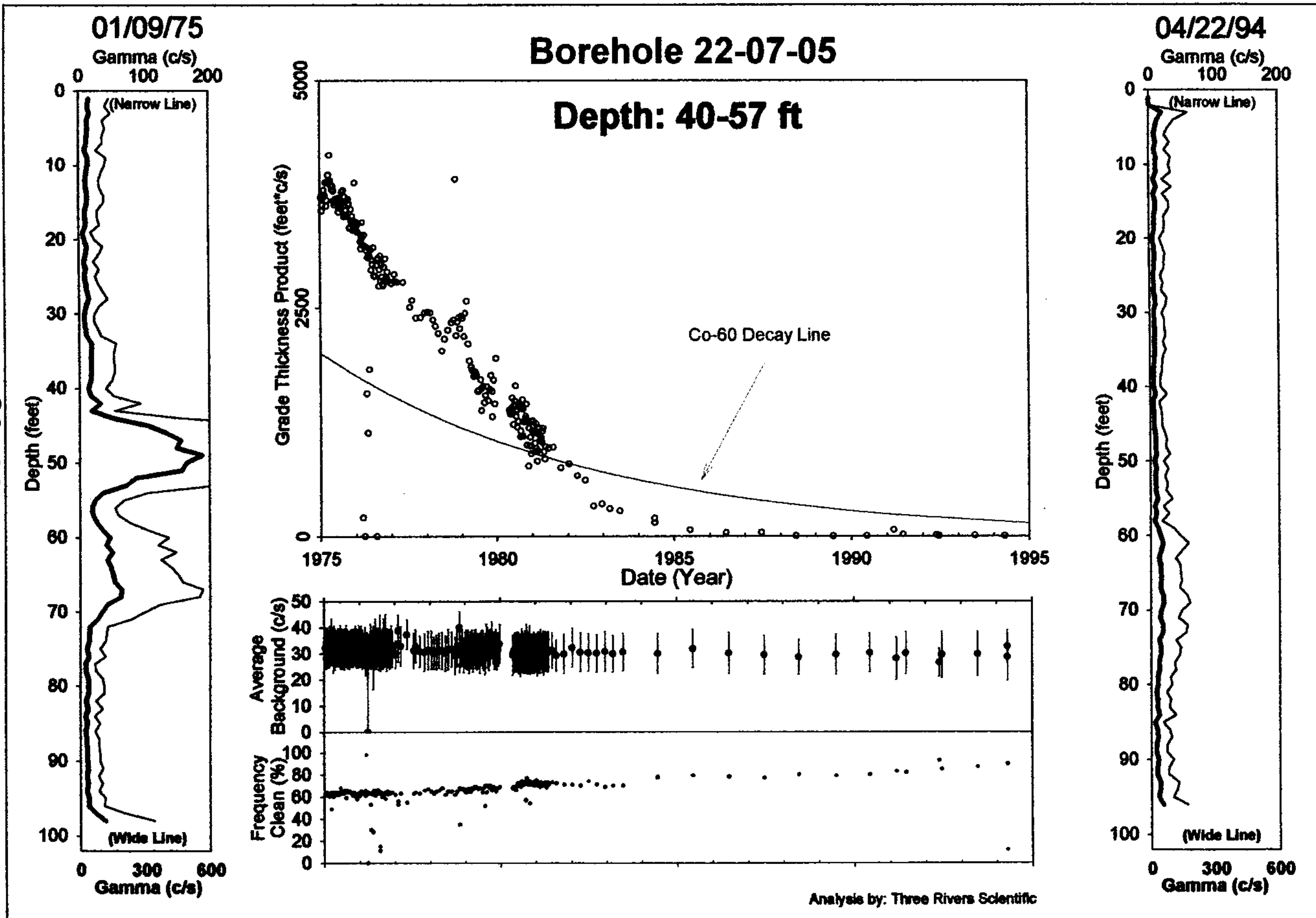
Borehole 22-07-05

Gross Gamma Survey Information

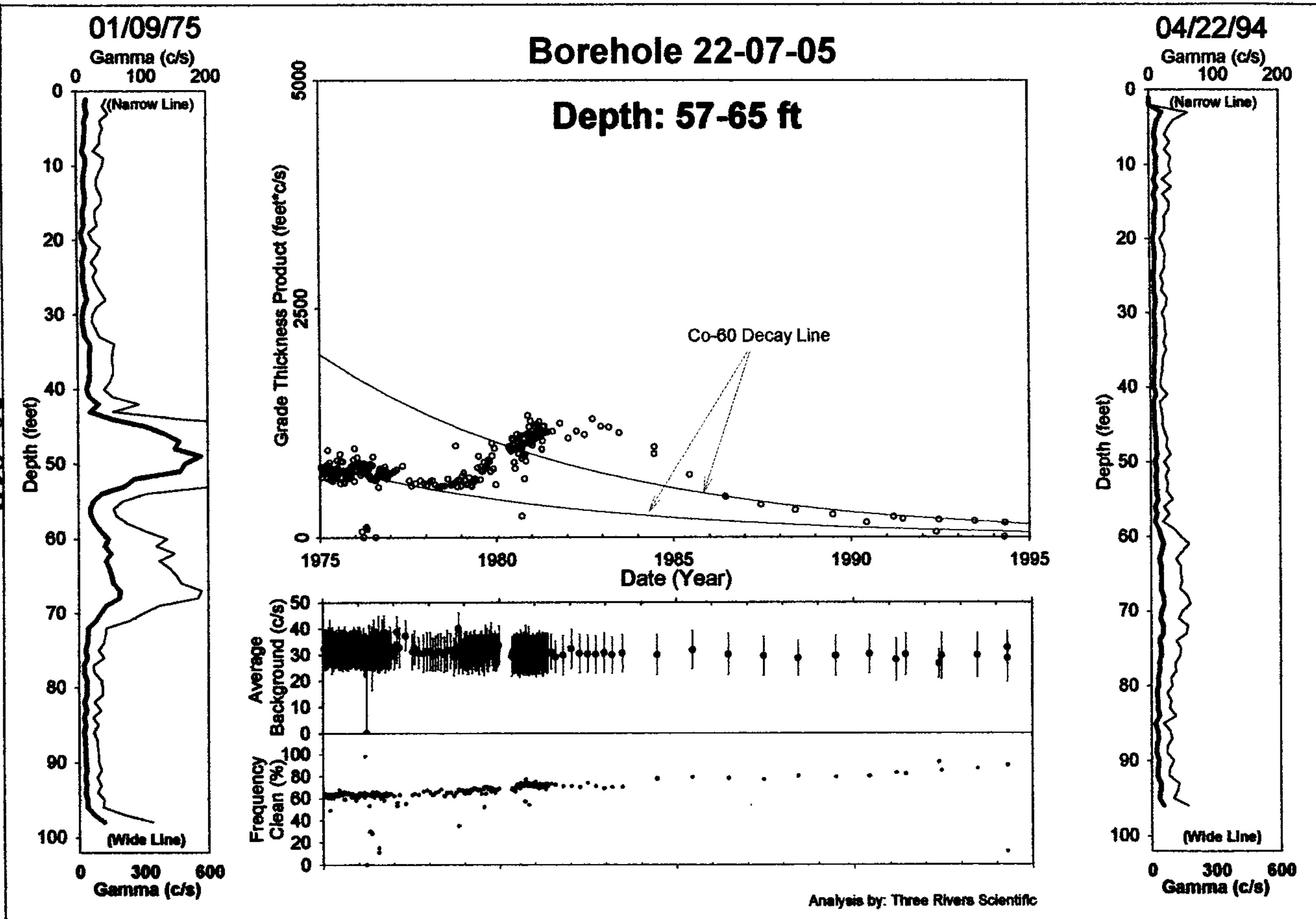
Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (5 surveys)
Borehole Depth :	97 ft
Survey Depth :	97 ft
First Survey Date :	1/09/1975
Last Survey Date :	4/22/1994
Number Surveys :	238

Analysis Notes

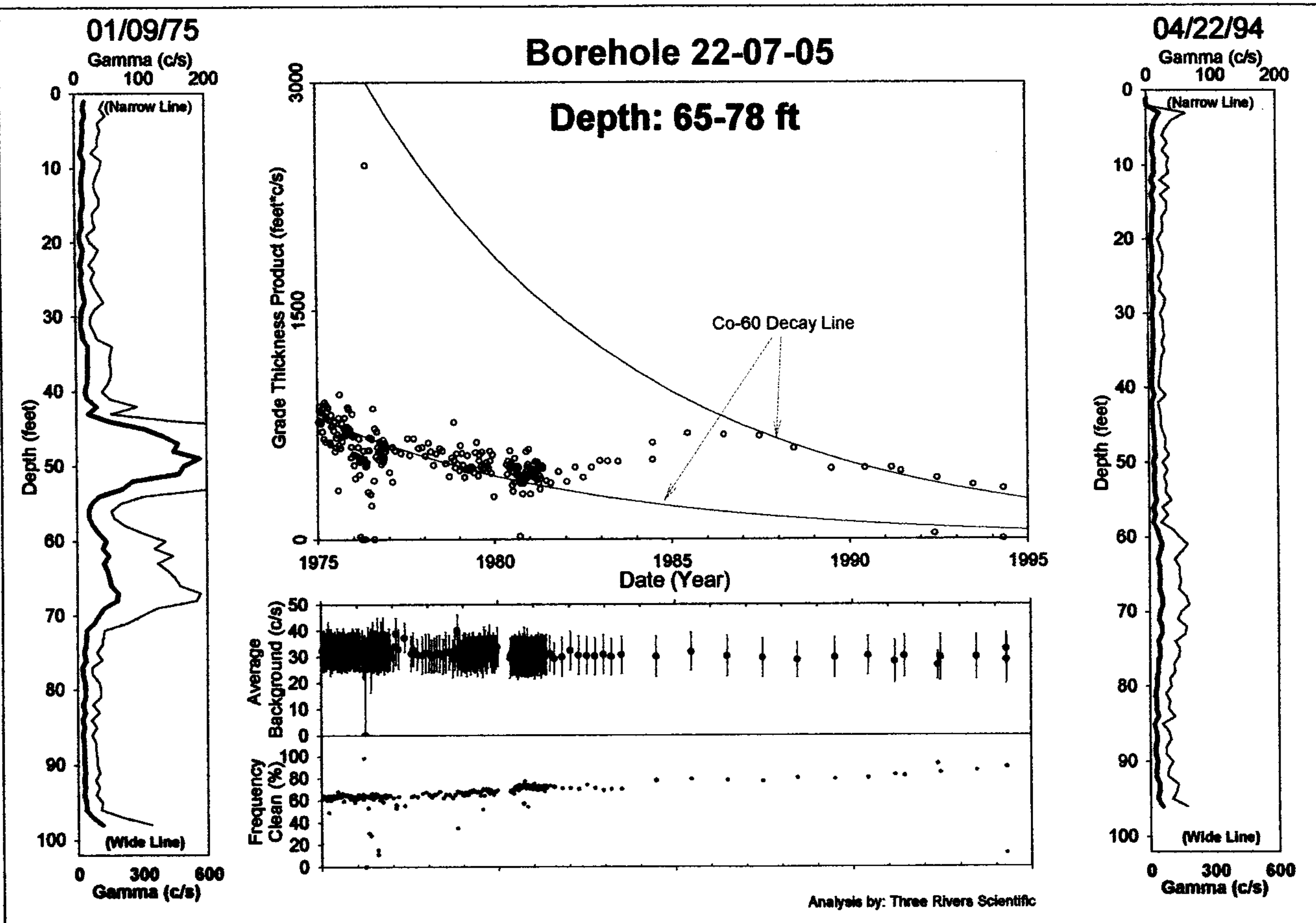
Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	10 to 35 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	40-57, 57-65, 65-78 feet is UNSTABLE 90-100 feet is Undetermined
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



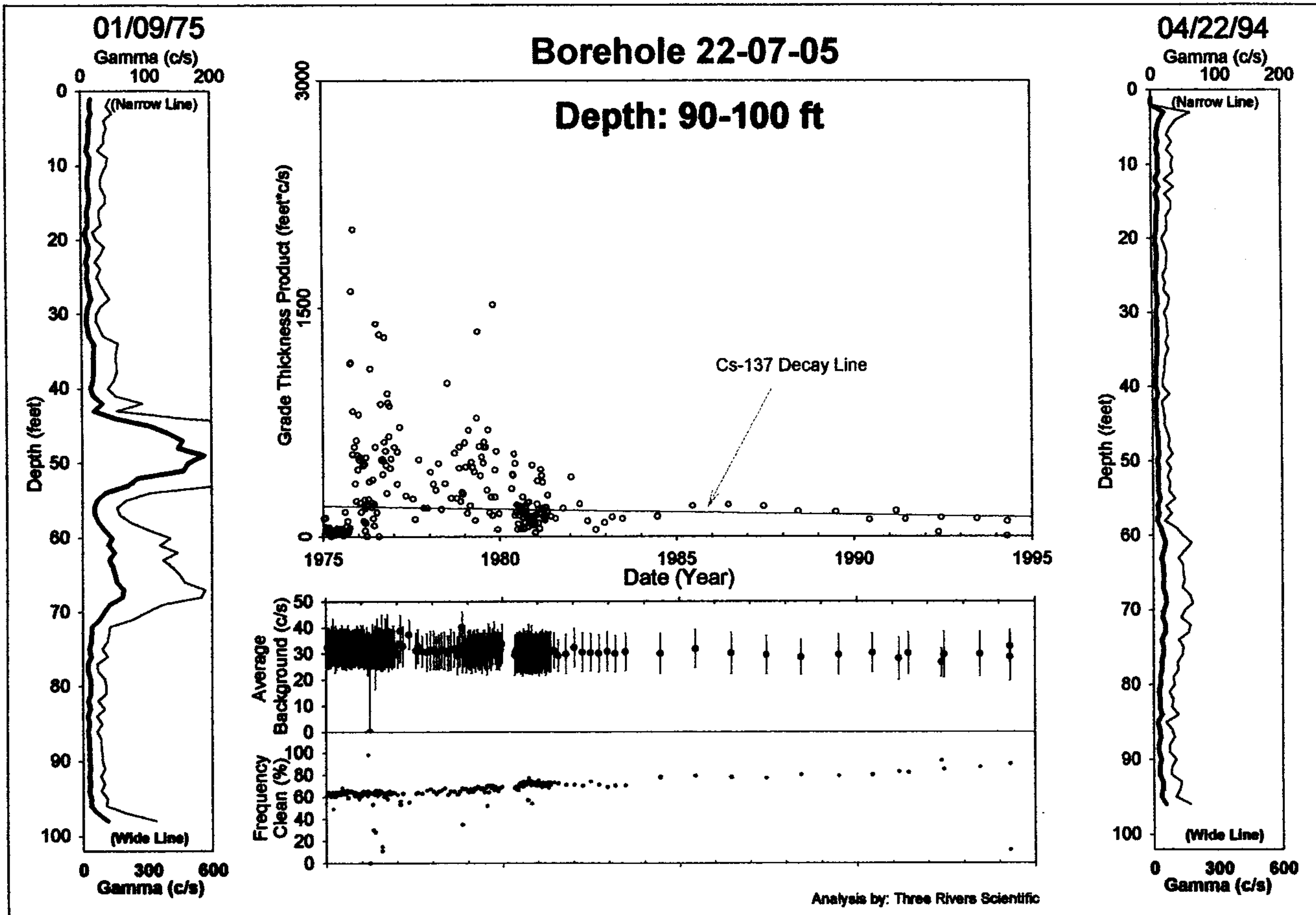
Borehole 22-07-05
Depth: 40-57 ft
01/09/75
Gamma (c/s)
0 100 200
(Narrow Line)
(Wide Line)
0 300 600
Gamma (c/s)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
Grade Thickness Product (feet*c/s)
0 2500 5000
Co-60 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
04/22/94
Gamma (c/s)
0 100 200
(Narrow Line)
(Wide Line)
0 300 600
Gamma (c/s)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100

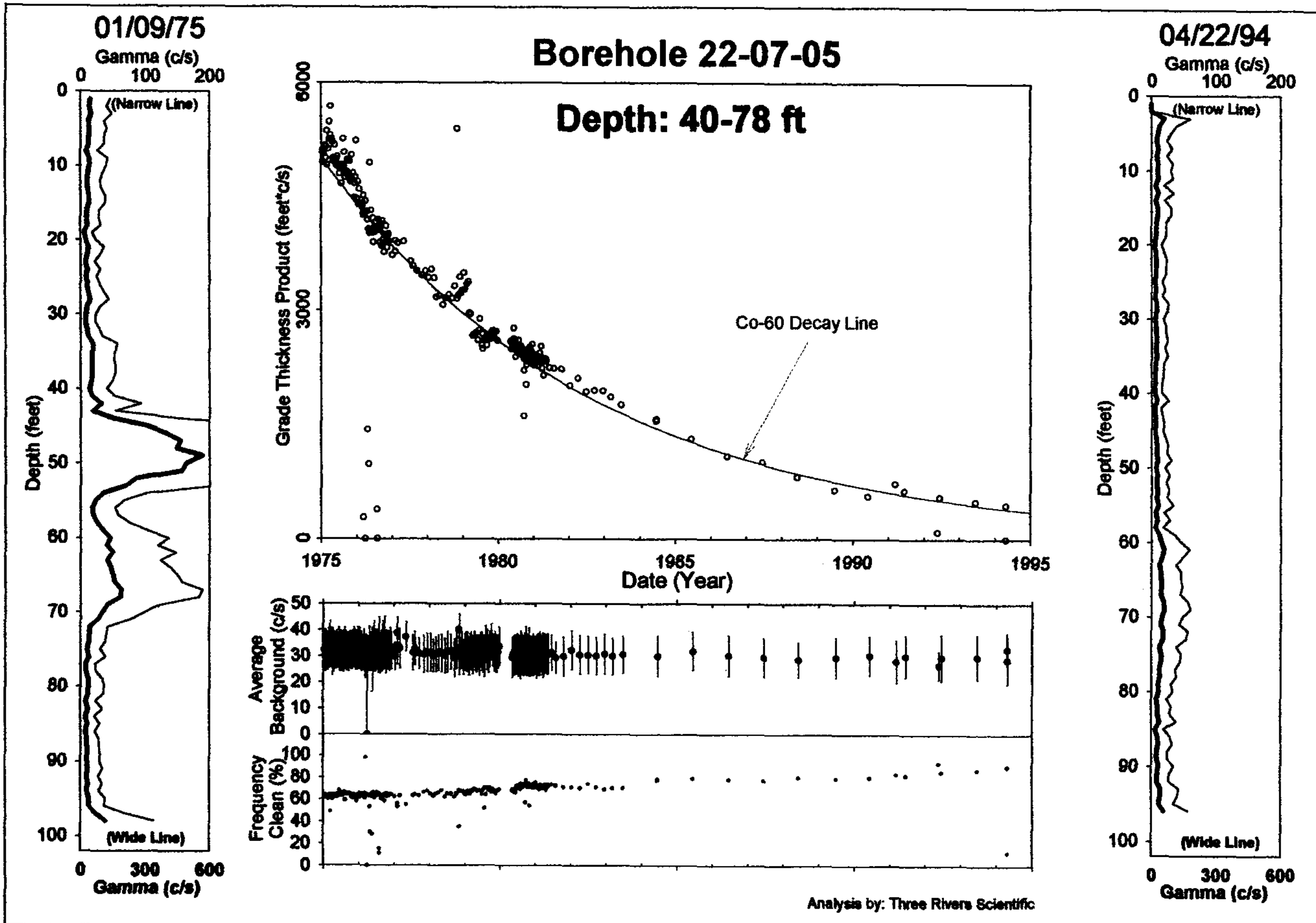


01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Borehole 22-07-05
Depth: 57-65 ft
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
04/22/94

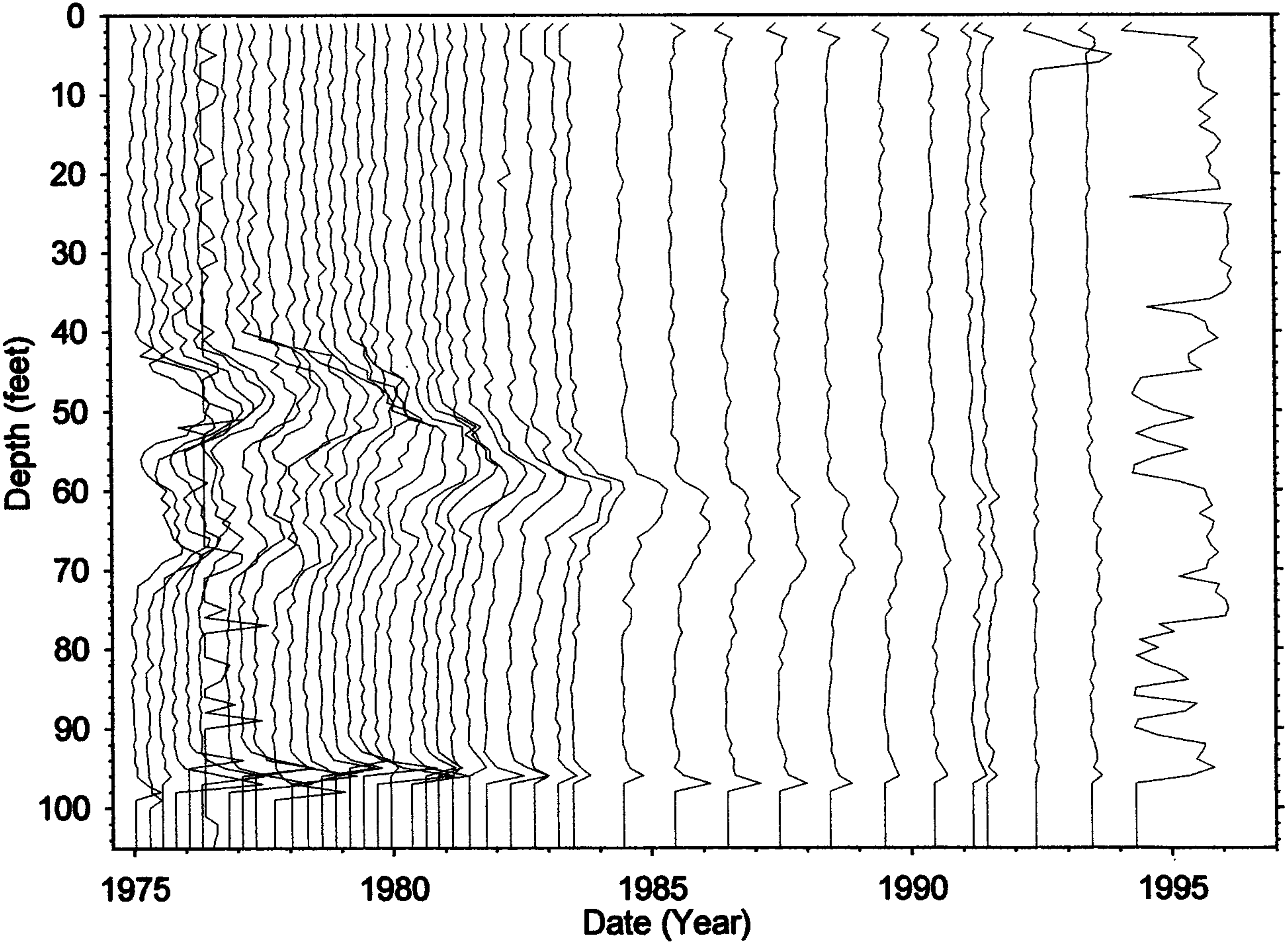

01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Borehole 22-07-05
Depth: 65-78 ft
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
04/22/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)

Borehole 22-07-05

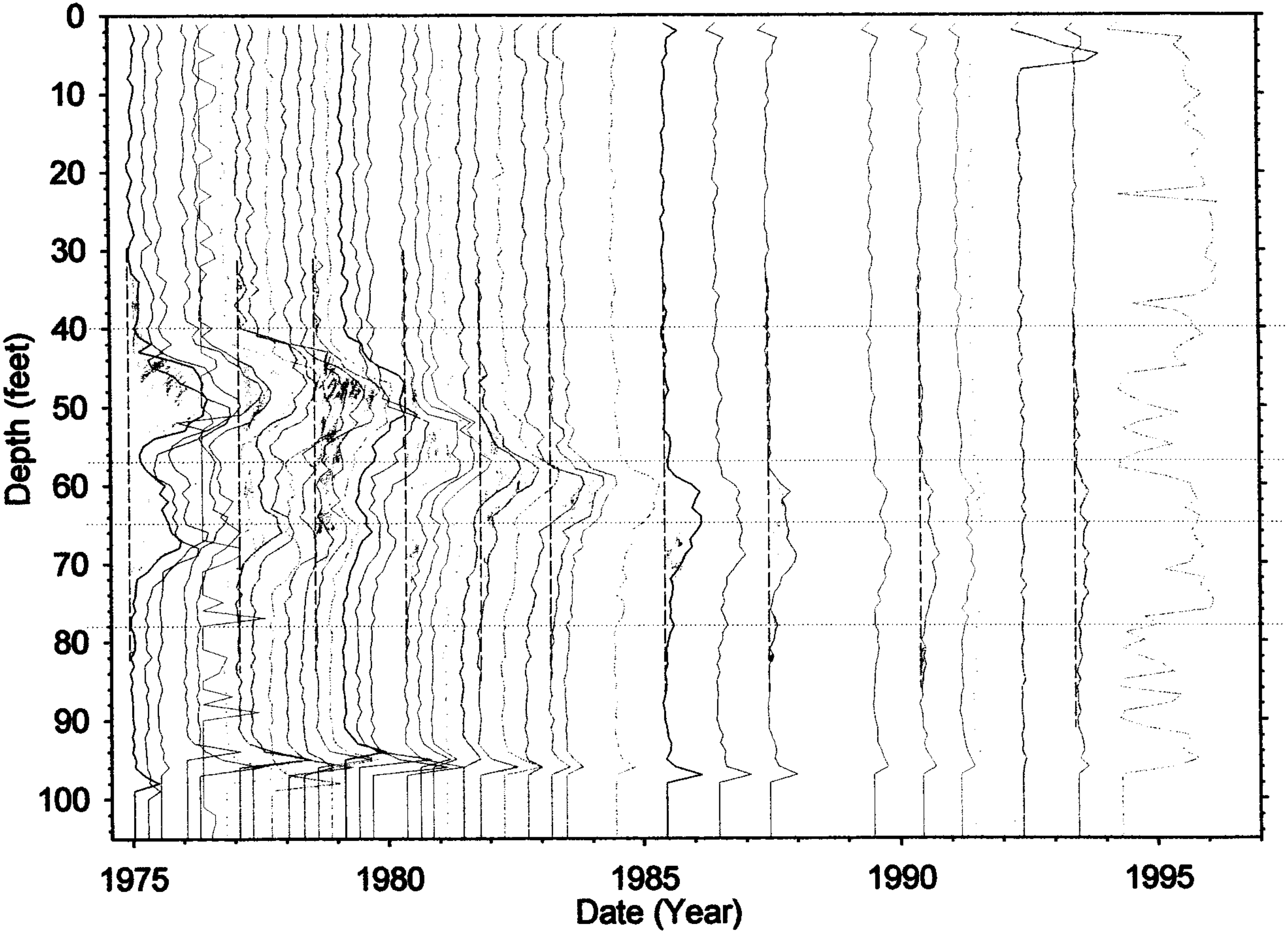



01/09/75
Gamma (c/s)
0 100 200
((Narrow Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
(Wide Line)
0 300 600
Gamma (c/s)
Borehole 22-07-05
Depth: 40-78 ft
Grade Thickness Product (feet*c/s)
0 3000 6000
Co-60 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
04/22/94
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
(Wide Line)
0 300 600
Gamma (c/s)

Borehole 22-07-05



Borehole 22-07-05



HNF-3532 -REV0

00 317

Borehole 22-07-07

Contamination (Cs-137 & Ru-106 & Sb-125) from 30-54 feet is UNSTABLE
Contamination (Co-60 & Sb-125) from 80-98 feet is UNSTABLE

Grade Thickness Product for radioactive zone (30-54 feet) is decreasing within the gross gamma sensitivity at a rate consistent with the decay of Ru-106 and Sb-125 (both hypotheses) and Cs-137 (identified from HPGe detector) from 1975 to 1980, then in 1981 the Grade Thickness Product decreases rapidly in a few months to background levels.

Grade Thickness Product for the radioactive zone (80-98 feet) is INCREASING in 1975 then from 1976 to 1983 has an erratic rate or decrease. The rate of decrease (since 1983) does not clearly identify the radionuclides that may have been present, other than Co-60 (identified from HPGe detector). The presence of Sb-125 (hypothesis) is considered because of its probable presence in the shallower zone and other boreholes in this Tank Farm. Two decay lines are presented. The decay line for Co-60 shows stability since about 1990. The decay line for Sb-125 and Co-60 shows stability since 1983.

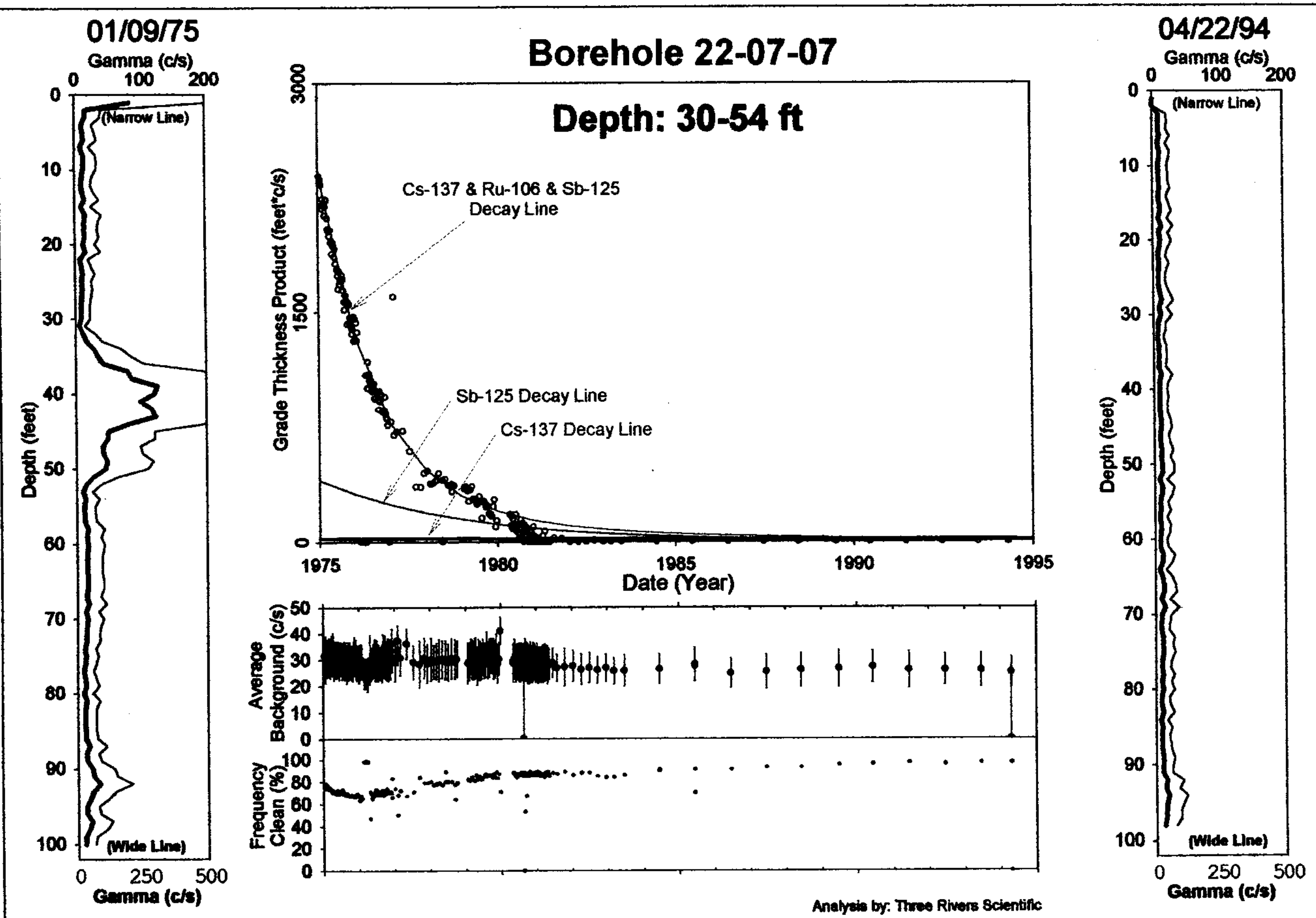
Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (2 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	4/22/1994
Number Surveys :	225

Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	55 to 80 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	30-54 feet is UNSTABLE 80-98 feet is UNSTABLE
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific

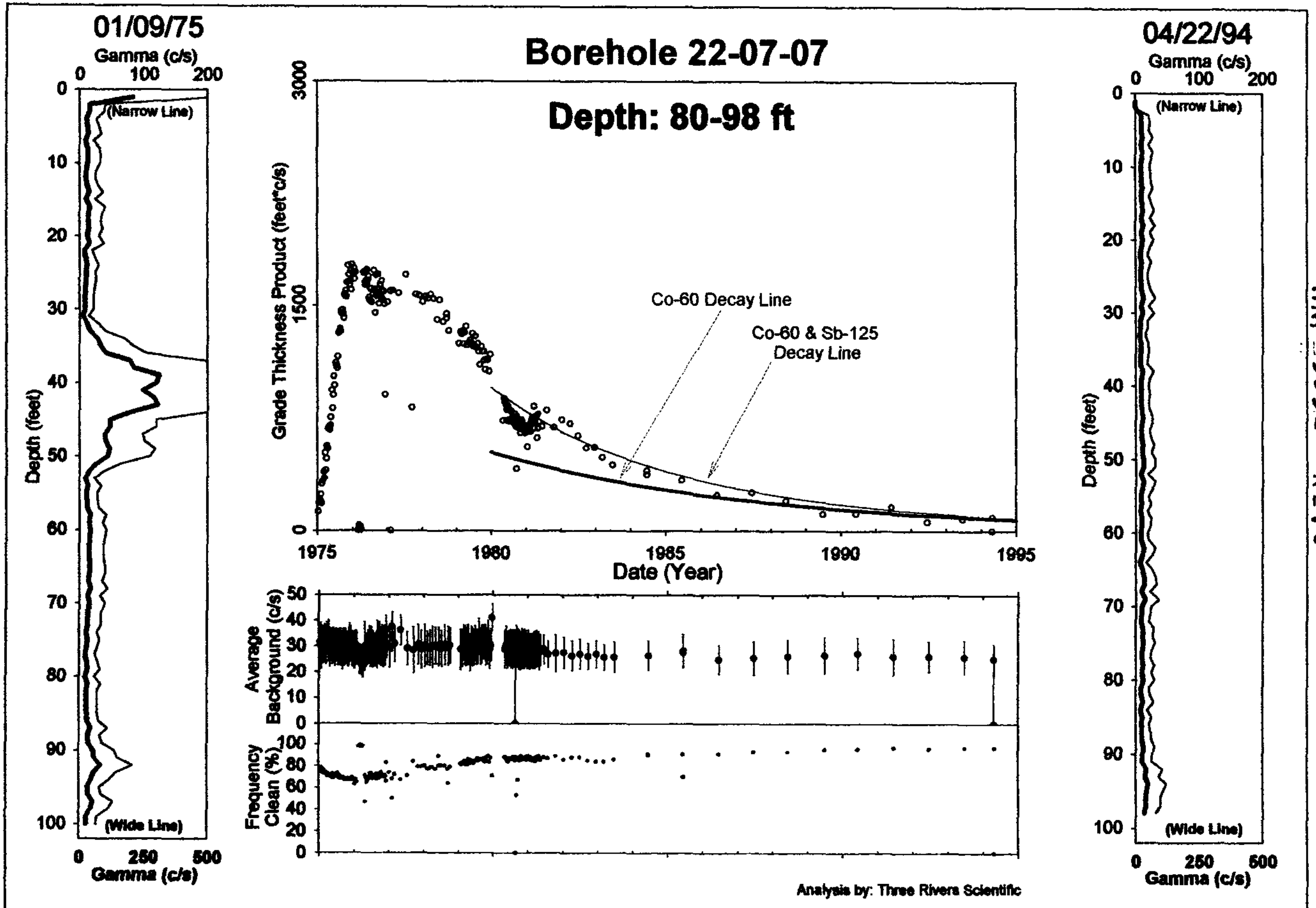
Borehole 22-07-07



Analysis by: Three Rivers Scientific

00 319

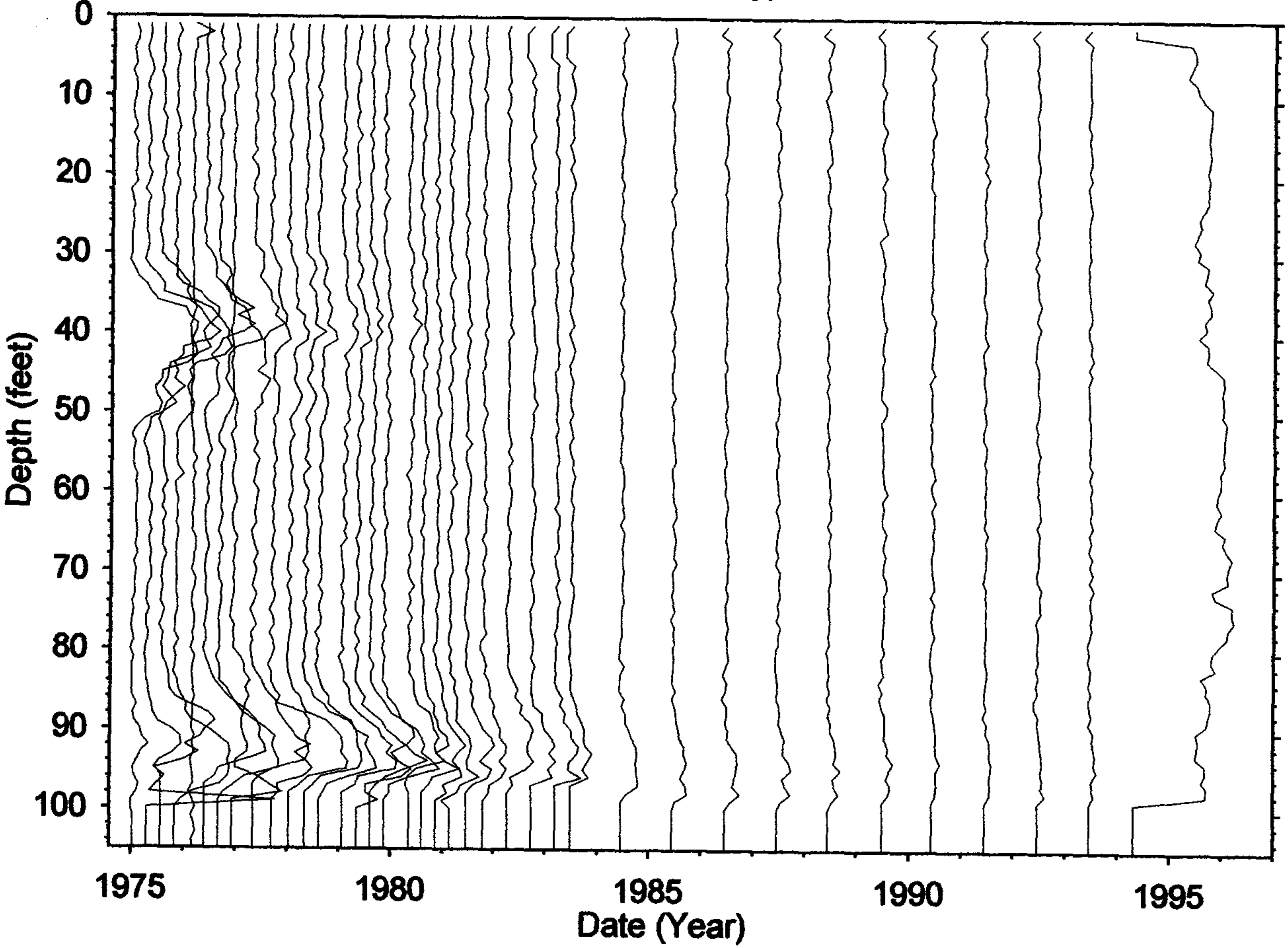
HNF-3532 -REV0



00 320

HNF-3532 -REV0

Borehole 22-07-07



HNF-3532 -REV0

00 321

Borehole 22-07-09

Contamination (Cs-137) from 0-9 feet is Tank Farm Activity
Contamination (Cs-137) from 9-17 feet is Stable
Contamination (Cs-137) from 17-36 feet is Appears Stable
Contamination (Cs-137) from 62-74 feet is **UNSTABLE**
Contamination (Co-60) from 74-84 feet is **UNSTABLE**
Contamination (Co-60) from 84-94 feet is **UNSTABLE**
Contamination (Co-60) from 94-100 feet is **UNSTABLE**

Grade Thickness Product from 0 to 9 feet is erratic in 1975 and from 1982 to 1986, and is categorized as Tank Farm activity. Grade Thickness Product is decreasing within counting statistics in two time intervals (1976-1982 and 1986-1994) at a rate consistent with Cs-137 (identified from HPGe detector).

Grade Thickness Product for the radioactive zone (9-17 feet) is decreasing within the gross gamma sensitivity at a rate consistent with the decay of Cs-137 (identified from HPGe detector) between 1975 and 1994.

Grade Thickness Product for the radioactive zone (17-36 feet) appears to be decreasing sensitivity at a rate consistent with the decay of Cs-137 (identified from HPGe detector) except prior to 1981. The gross gamma activity is at the 30,000 counts per second rate which may be beyond the linear region of the counting system.

Grade Thickness Product for radioactive zone (62-74 feet) is INCREASING from 1975 to mid-year 1976 then is decreasing at a rate that would appear to be stable contamination. However, the stack plot shows the migration of contamination out of this zone (i.e. vertical movement to lower depths), therefore, fitting the decrease in grade thickness product to a radionuclide decay would be incorrect since movement is apparent. The grade thickness product fits the decay of Cs-137 (identified from HPGe detector) from 1987 to 1995.

Grade Thickness Product for the radioactive zone (74-84 feet) has two time intervals of INCREASING radioactivity (1975-1978 and 1980-1982) followed by decreases. The decrease would appear to be stable contamination, however, the stack plot shows migration down from this zone to the lower zones. Therefore, fitting the decrease in grade thickness product to radioactive decay would be incorrect even though the decrease is consistent with the decay of Antimony-125 (hypothesis) and Cobalt-60 (identified from HPGe detector). The grade thickness product does not fit the decay of Co-60 (HPGe identified) until very recently from 1990 to 1995.

Borehole 22-07-09

Grade Thickness Product for the radioactive zone (84-94 feet) shows background activity from 1975 to 1982, then INCREASING radioactivity from 1982 to 1985. The Grade Thickness Product has been decreasing from 1989 to 1995 at a rate consistent with the decay of Co-60 (identified from HPGe detector) within observed systematic limitations.

Grade Thickness Product for the radioactive zone (94-100 feet) shows background activity from 1975 to 1984, then INCREASING radioactivity from 1984 to 1986. The Grade Thickness Product has been decreasing from 1990 to 1995 at a rate consistent with the decay of Co-60 (identified from HPGe detector) within observed systematic limitations.

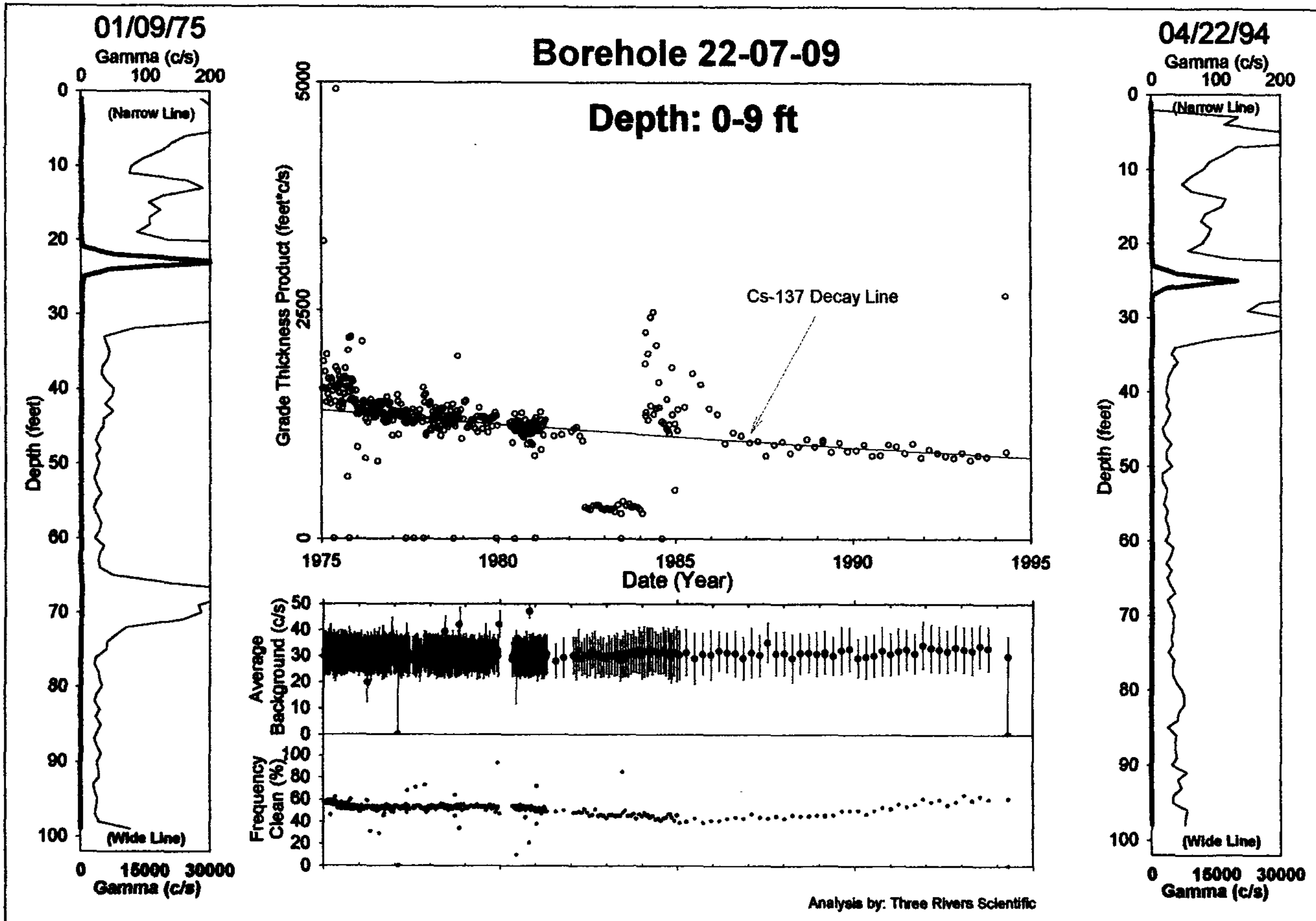
Grade Thickness Product for the combined radioactive zone (62-100 feet) shows three time intervals of INCREASED radioactivity (1975, 1980, 1984). The Grade Thickness Product has been decreasing within observed systematic limitations at a rate consistent with the decay of Co-60 (identified from HPGe detector) from 1990 to 1995.

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (4 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	4/22/1994
Number Surveys :	393

Analysis Notes

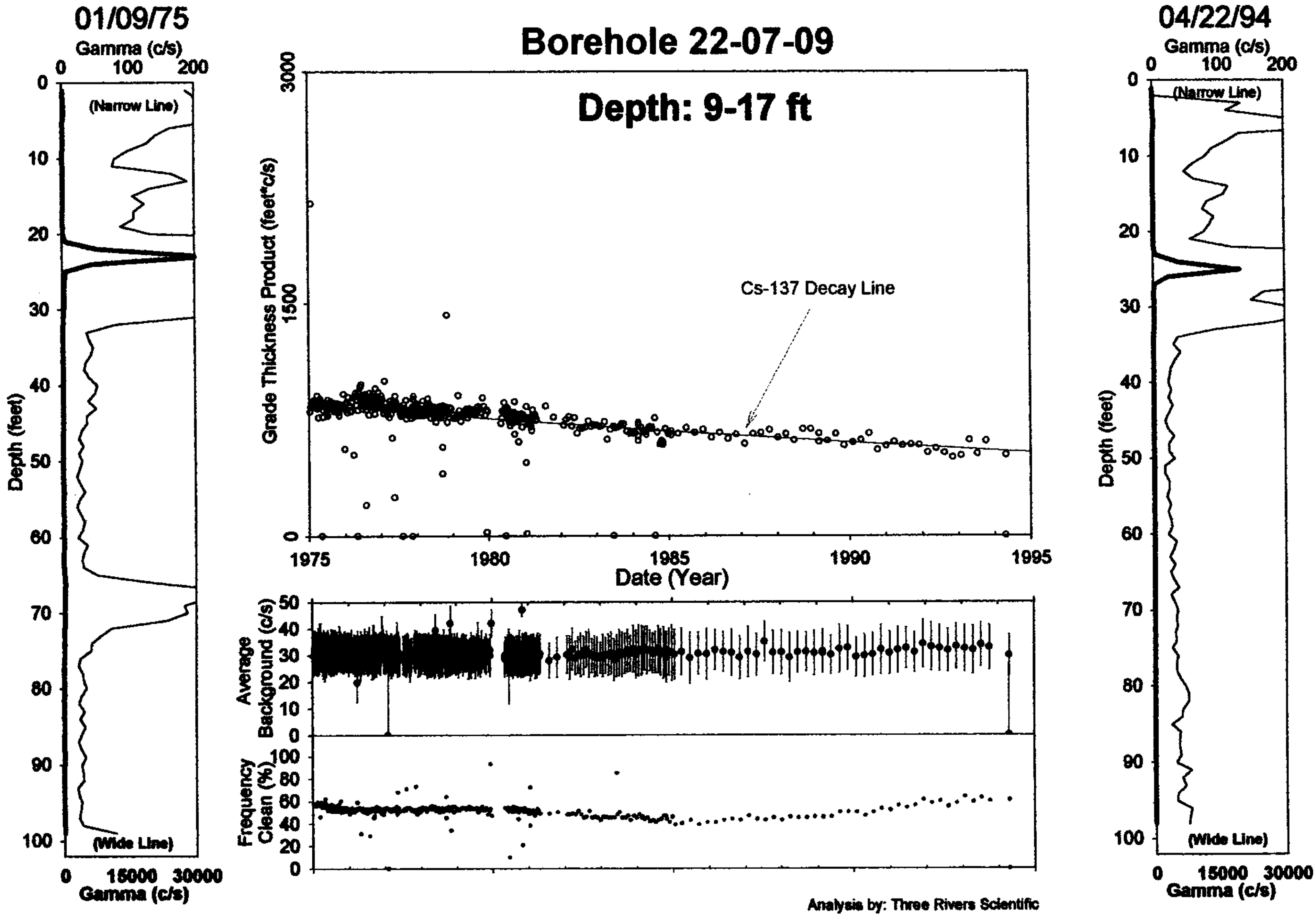
Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	40 to 60 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-9 feet is TF Activity 9-17 feet is Stable 17-36 feet Appears Stable 62-74, 74-84, 84-94, and 94-100 feet are UNSTABLE
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



01/09/75
Gamma (c/s)
0 100 200
(Narrow Line)
(Wide Line)
0 15000 30000
Gamma (c/s)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
Borehole 22-07-09
Depth: 0-9 ft
Grade Thickness Product (feet*c/s)
0 2500 5000
Cs-137 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
04/22/94
Gamma (c/s)
0 100 200
(Narrow Line)
(Wide Line)
0 15000 30000
Gamma (c/s)
Depth (feet)

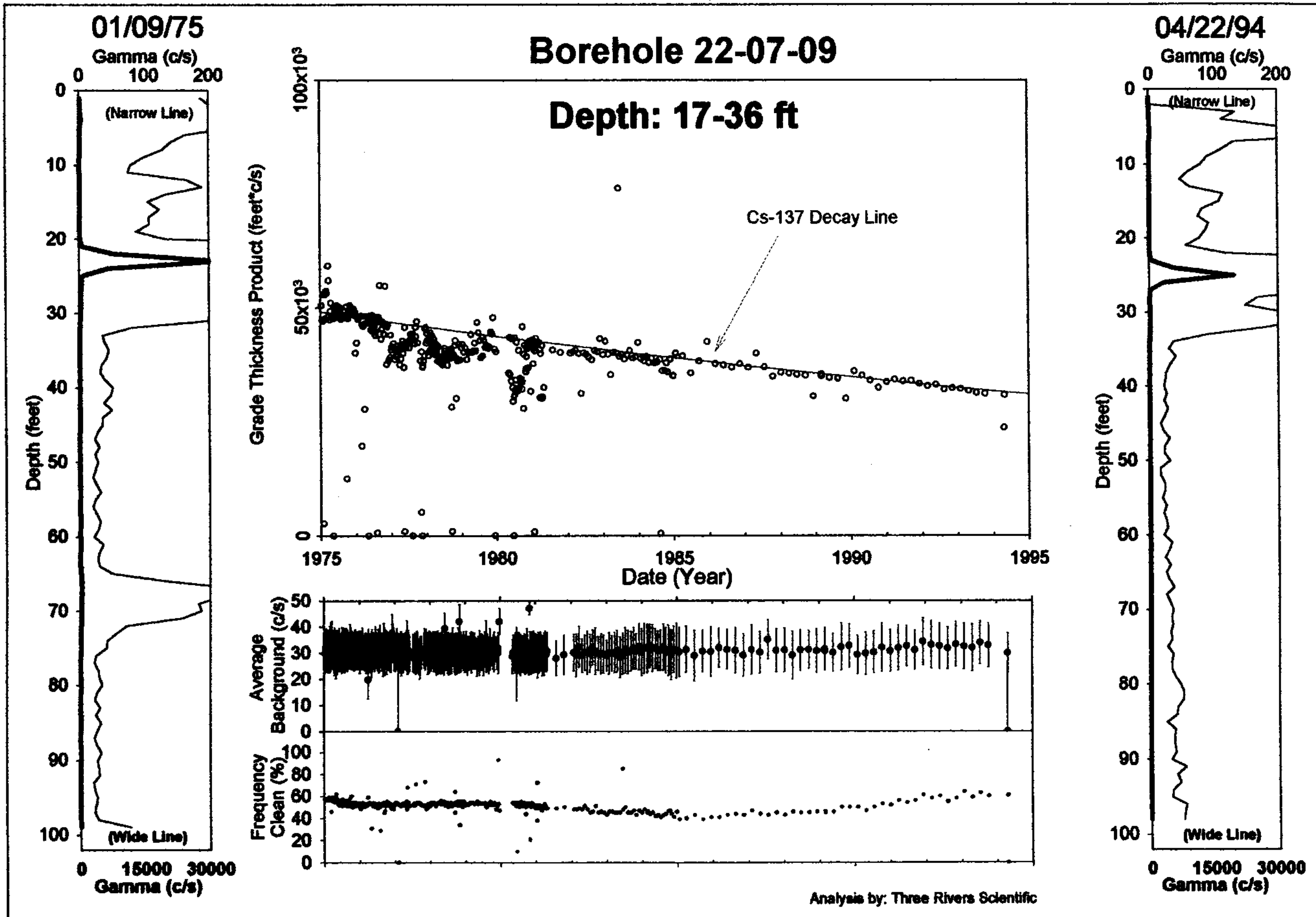
00 324

Borehole 22-07-09



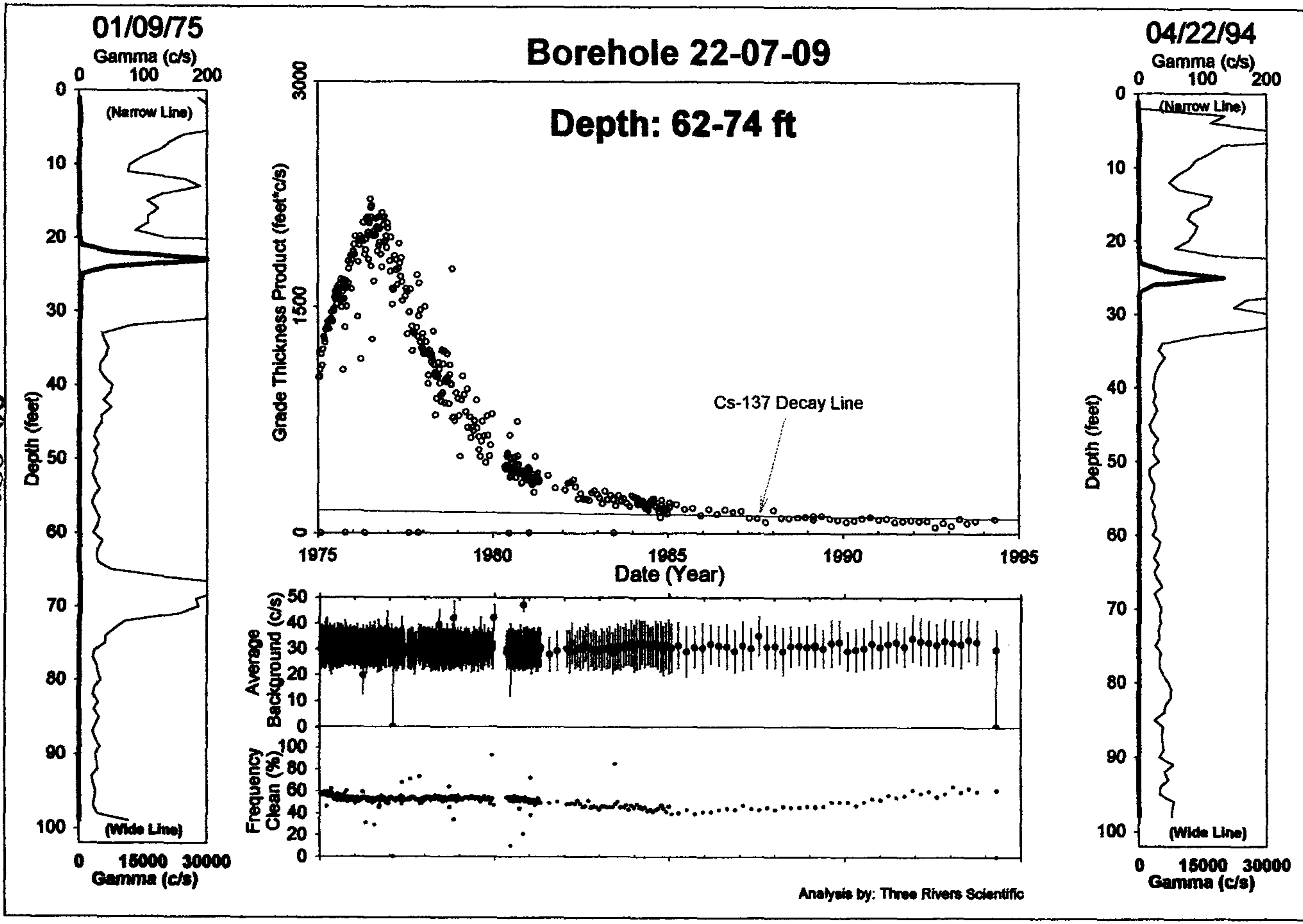
00 325

HNF-3532 -REV0



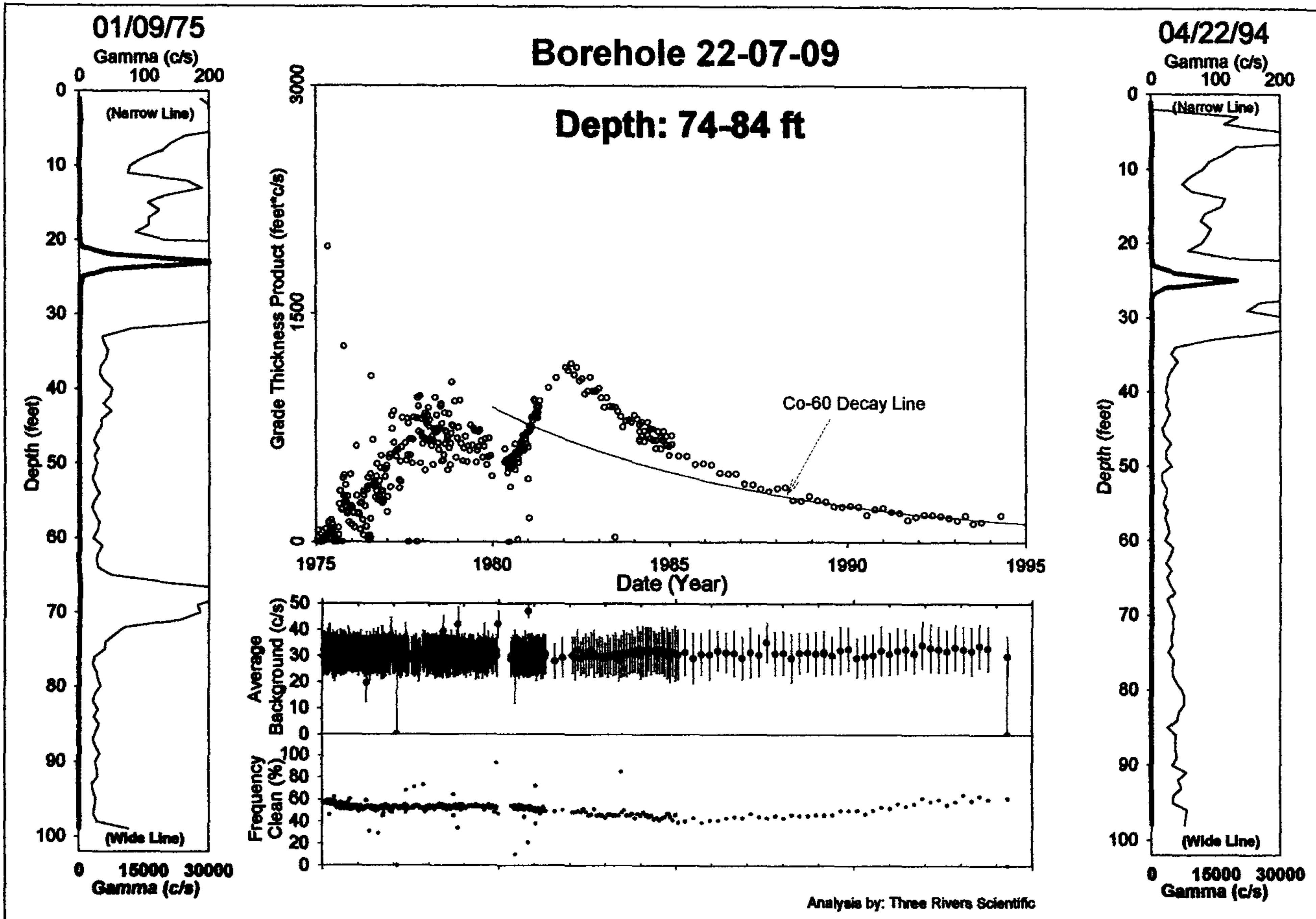
HNF-3532 -REV0

926 00 326



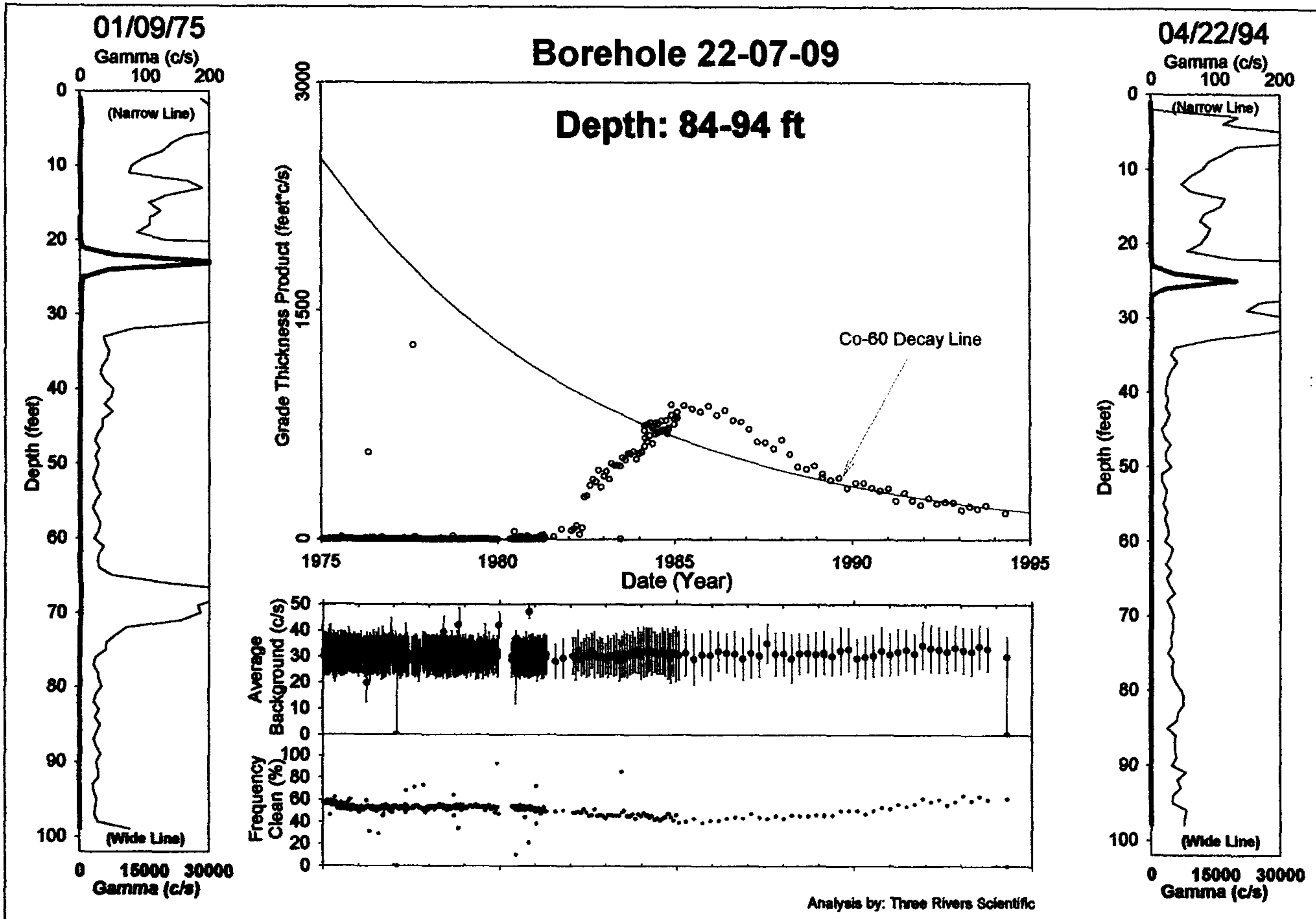
HNF-3532 -REV0

00 327



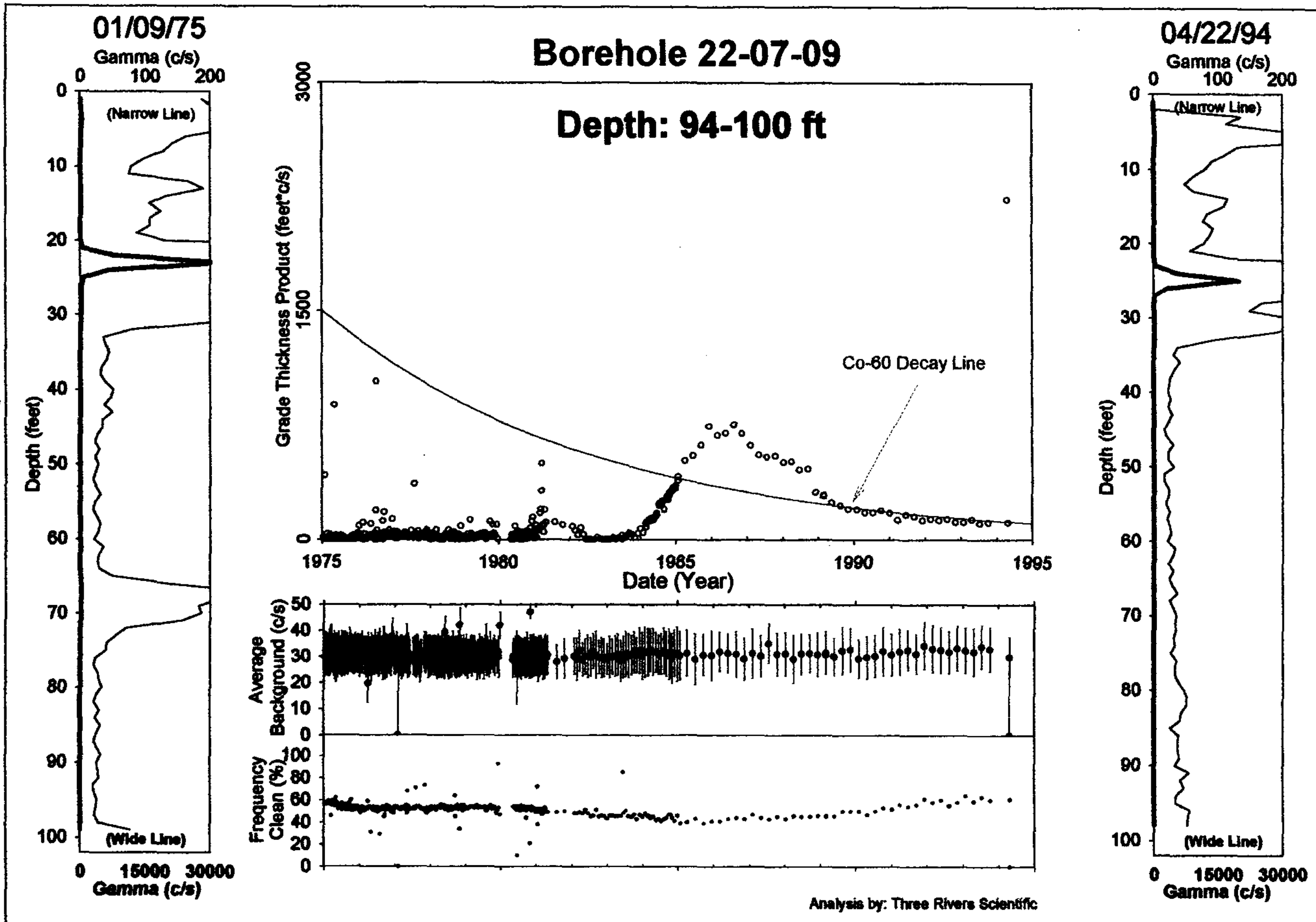
HNF-3532 -REV0

00 328



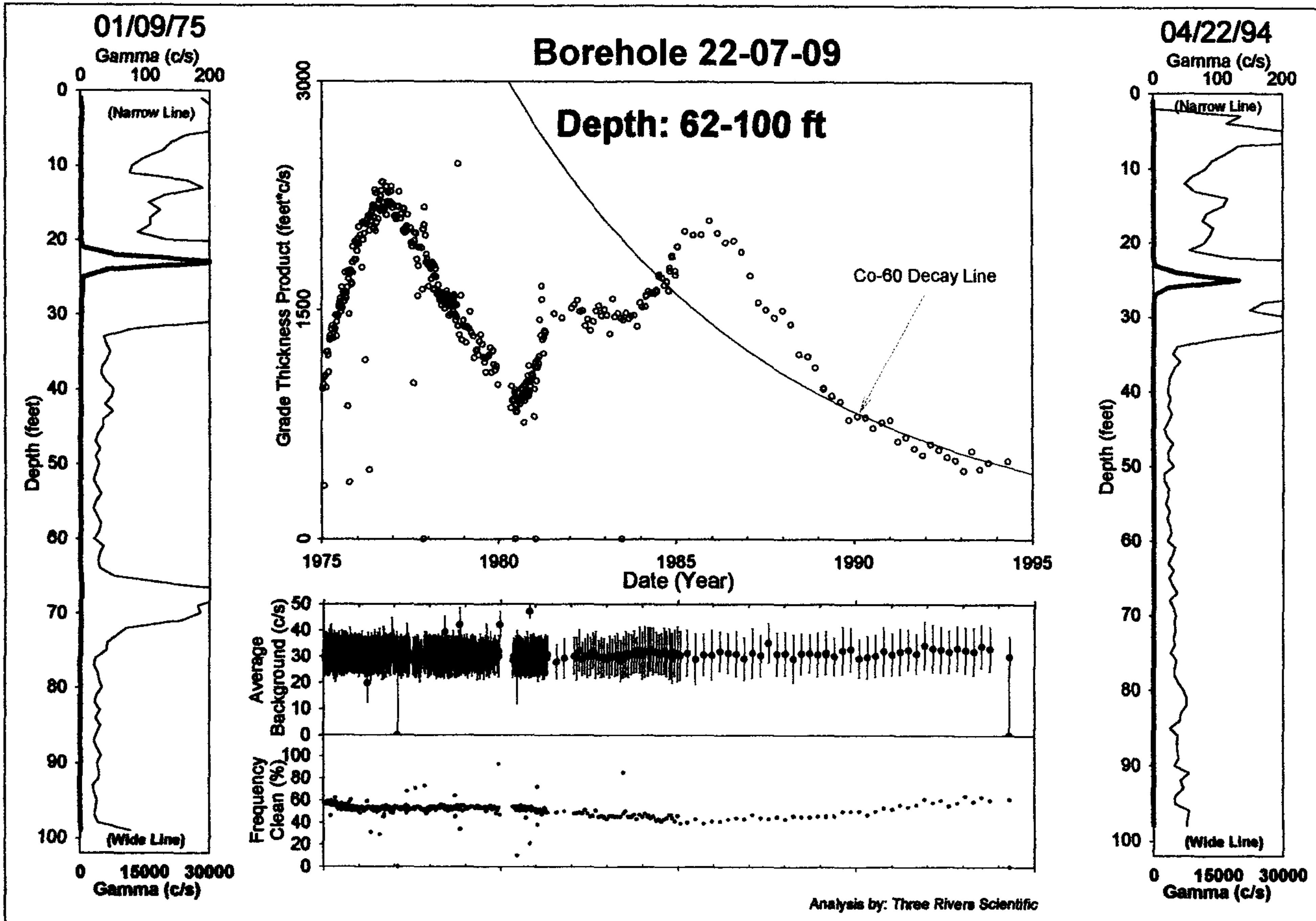
00 329

HNF-3532 -REV0



00 330

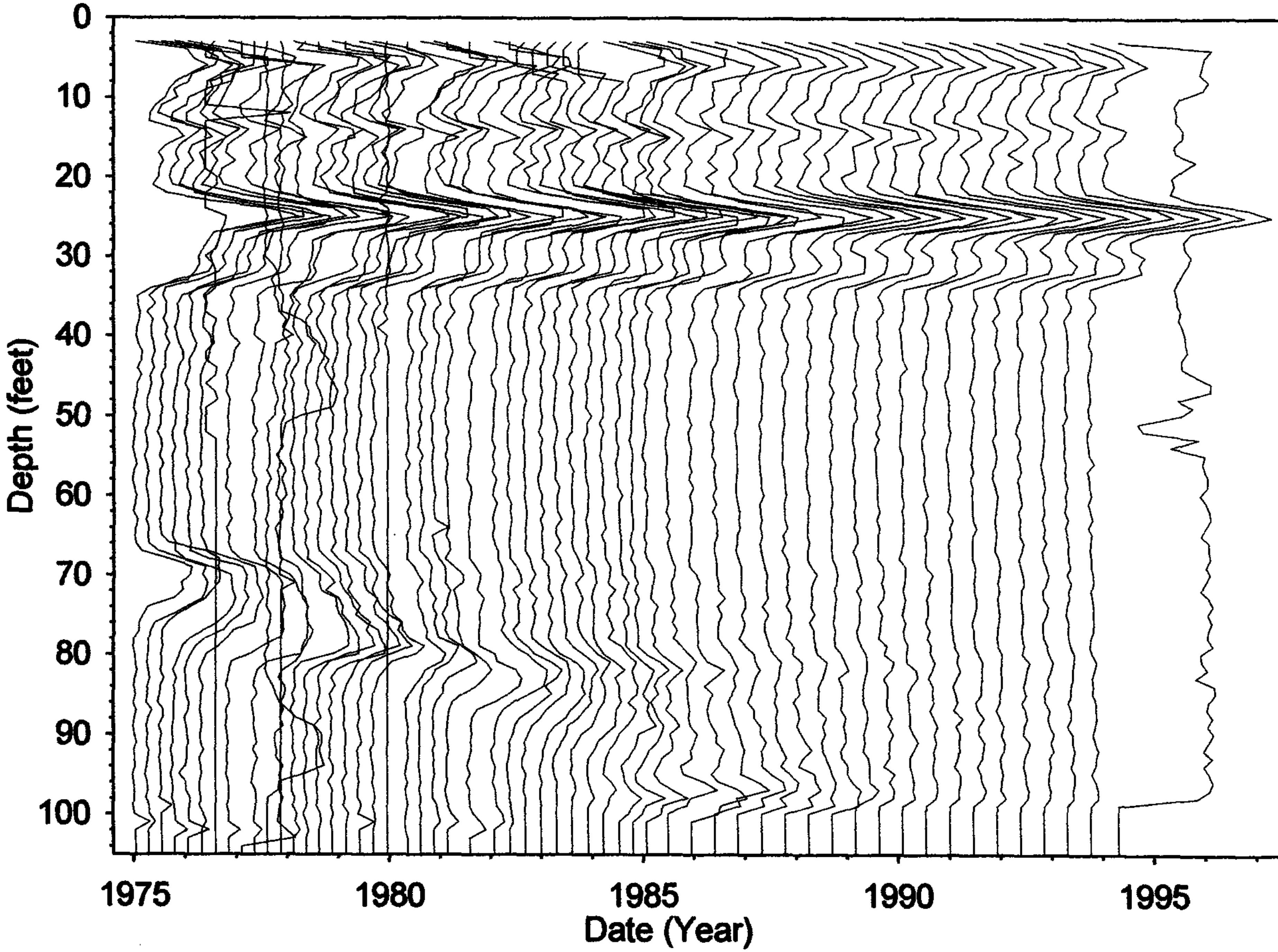
HNF-3532 -REV0



00 331

HNF-3532 -REV0

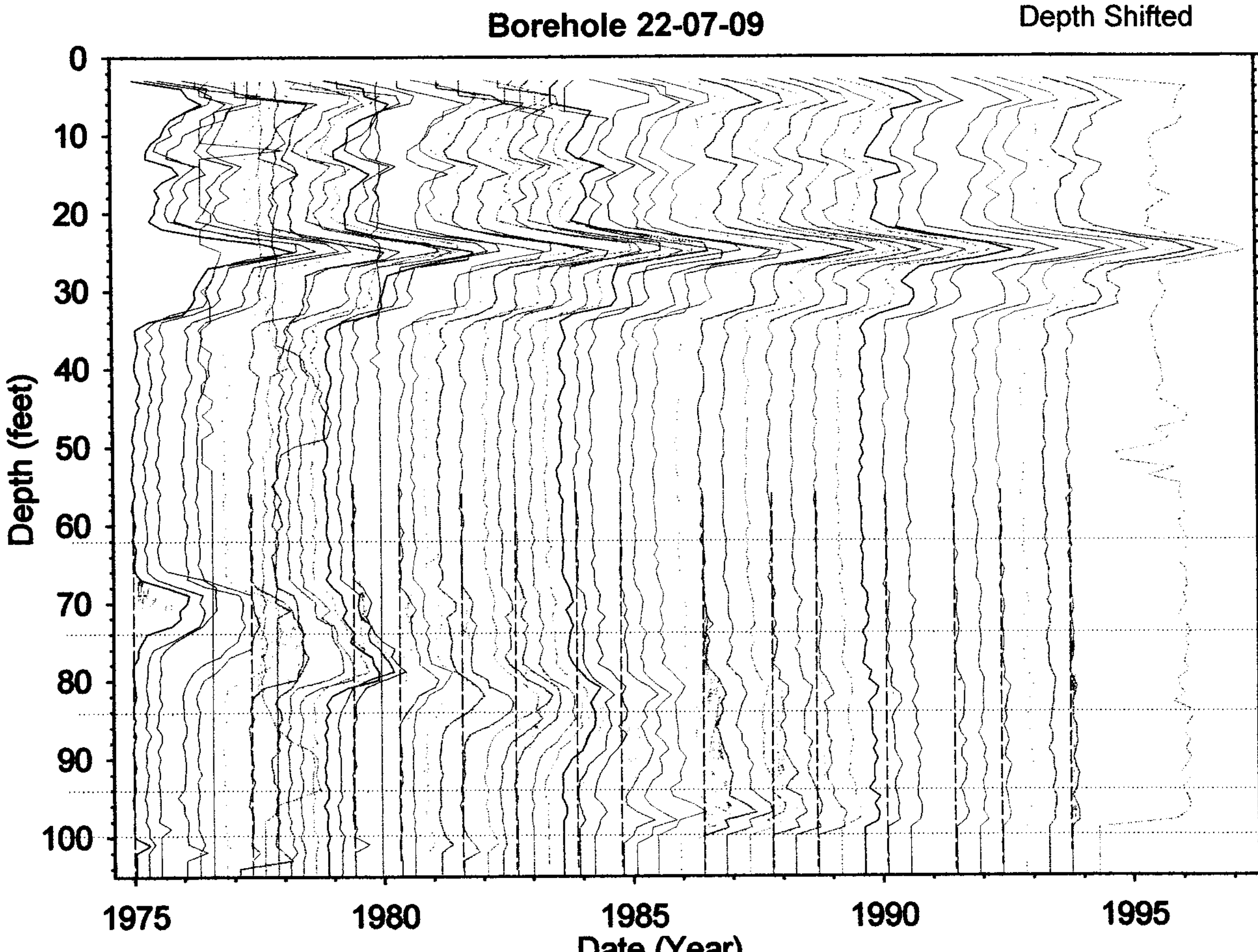
Borehole 22-07-09 Depth Shifted



HNF-3532 -REV0

332 00

Depth Shifted



HNF-3532 -REV0

00 333

Borehole 22-07-10

Contamination (Cs-137) from 0-6 feet is Tank Farm Activity
Contamination (Cs-137) from 6-12 feet is Stable
Contamination (Cs-137) from 12-20 feet is Stable
Contamination (Cs-137) from 20-30 feet is Stable
Contamination (Cs-137) from 30-44 feet is Stable

Grade Thickness Product from 0 to 6 feet is erratic for the 20 years of surveillance logging. The decay line for Cs-137 (identified from HPGe detector) is shown on the plot but is not fitted to any set of survey data.

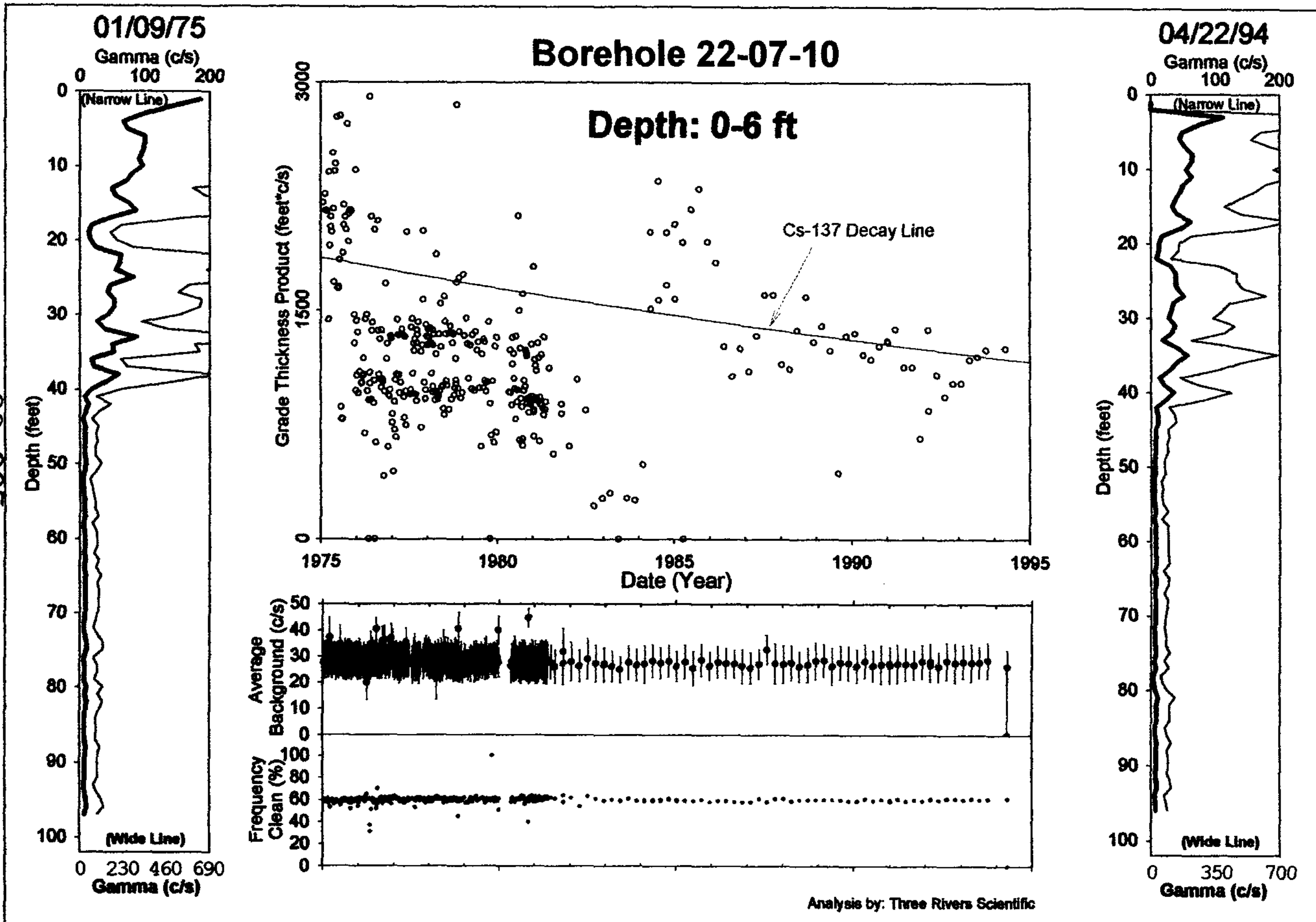
Grade Thickness Product for the four radioactive zones (6-12, 12-20, 20-30, and 30-44 feet) is decreasing within the gross gamma sensitivity at a rate consistent with the decay of Cs-137 (identified from HPGe detector) between 1975 and 1994.

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (4 surveys)
Borehole Depth :	97 ft
Survey Depth :	97 ft
First Survey Date :	1/09/1975
Last Survey Date :	4/22/1994
Number Surveys :	356

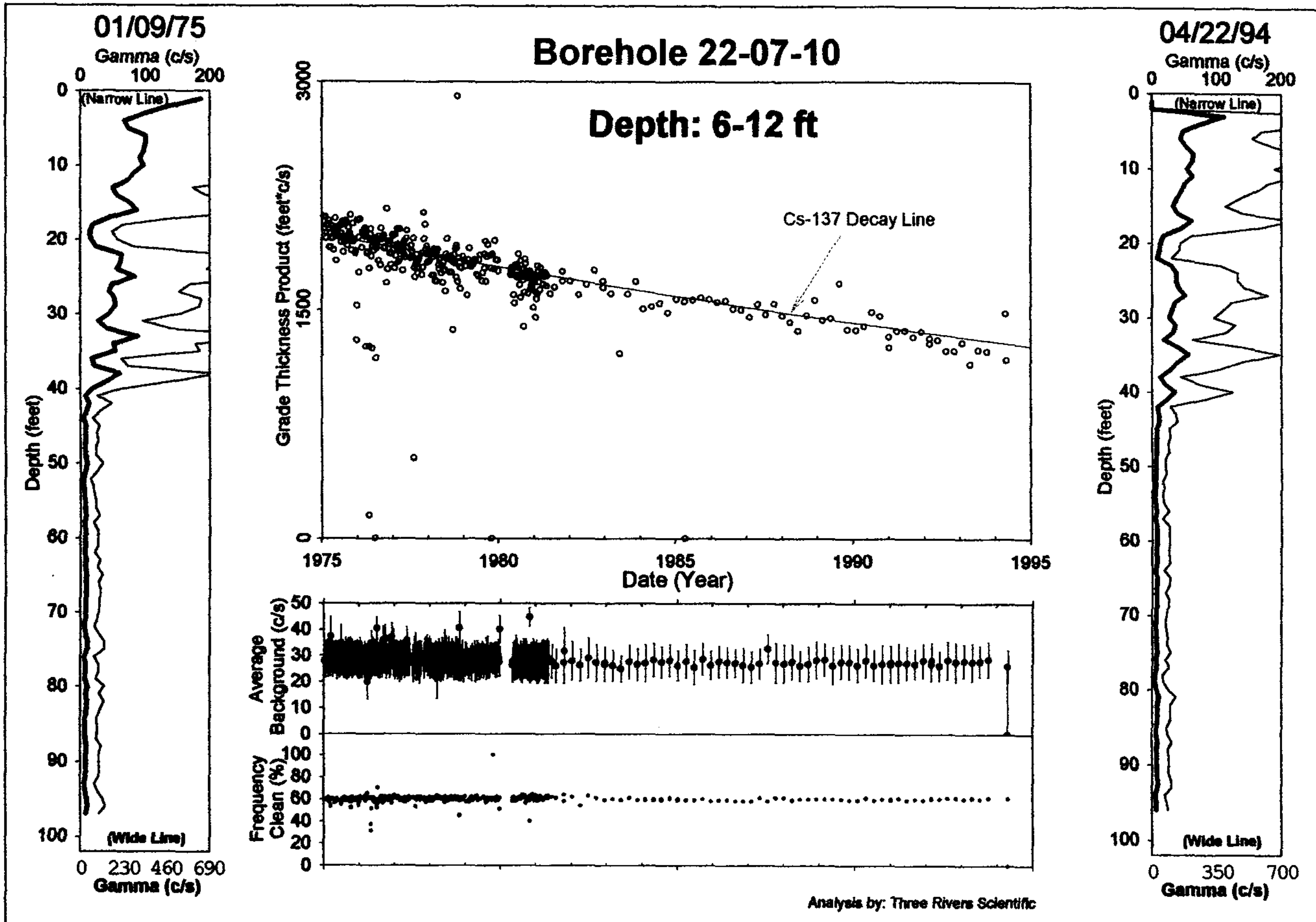
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	45 to 70 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-6 feet is TF Activity 6-12, 12-20, 20-30, 30-44 feet are Stable
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific

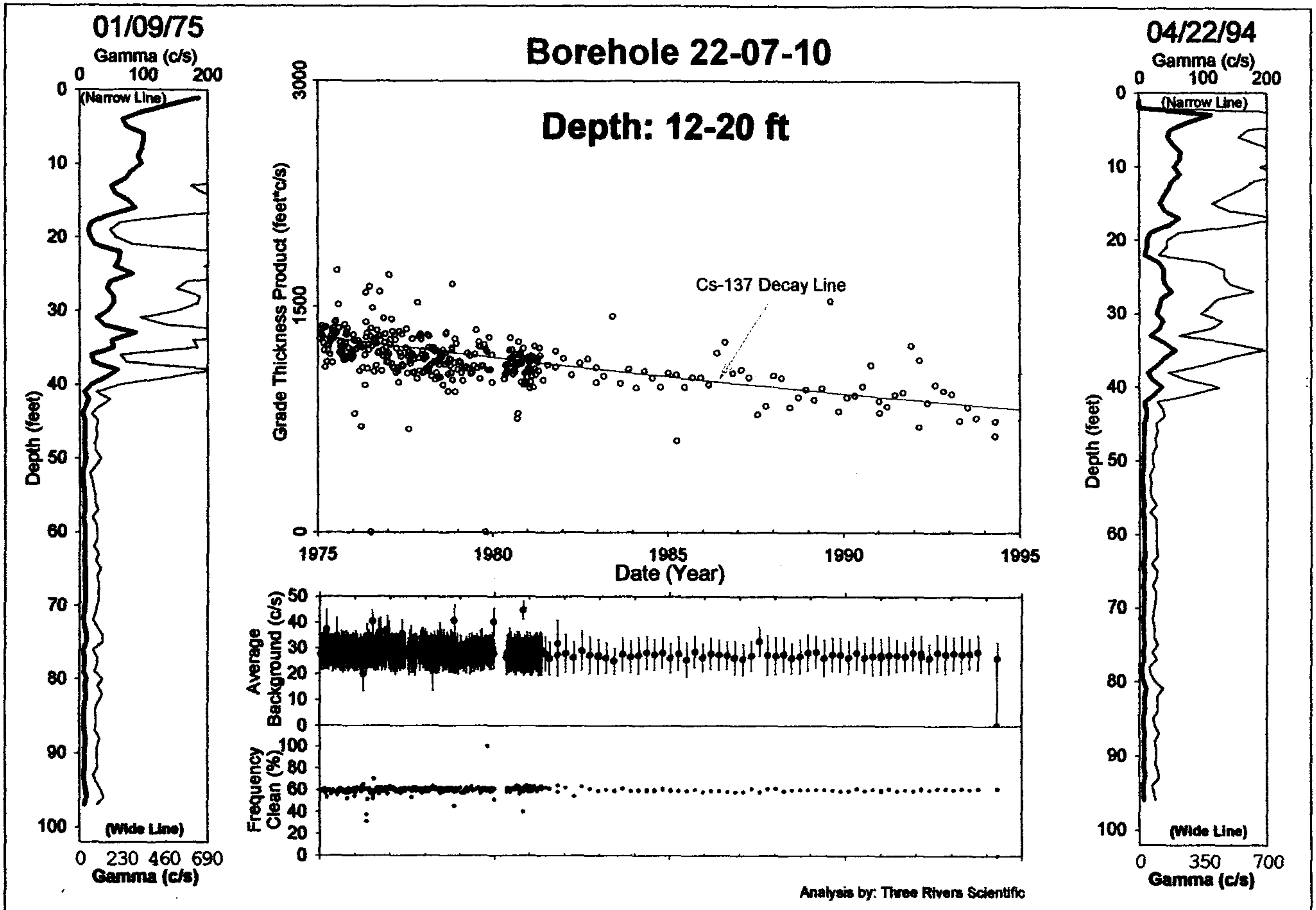


00 335

HNF-3532 -REV0

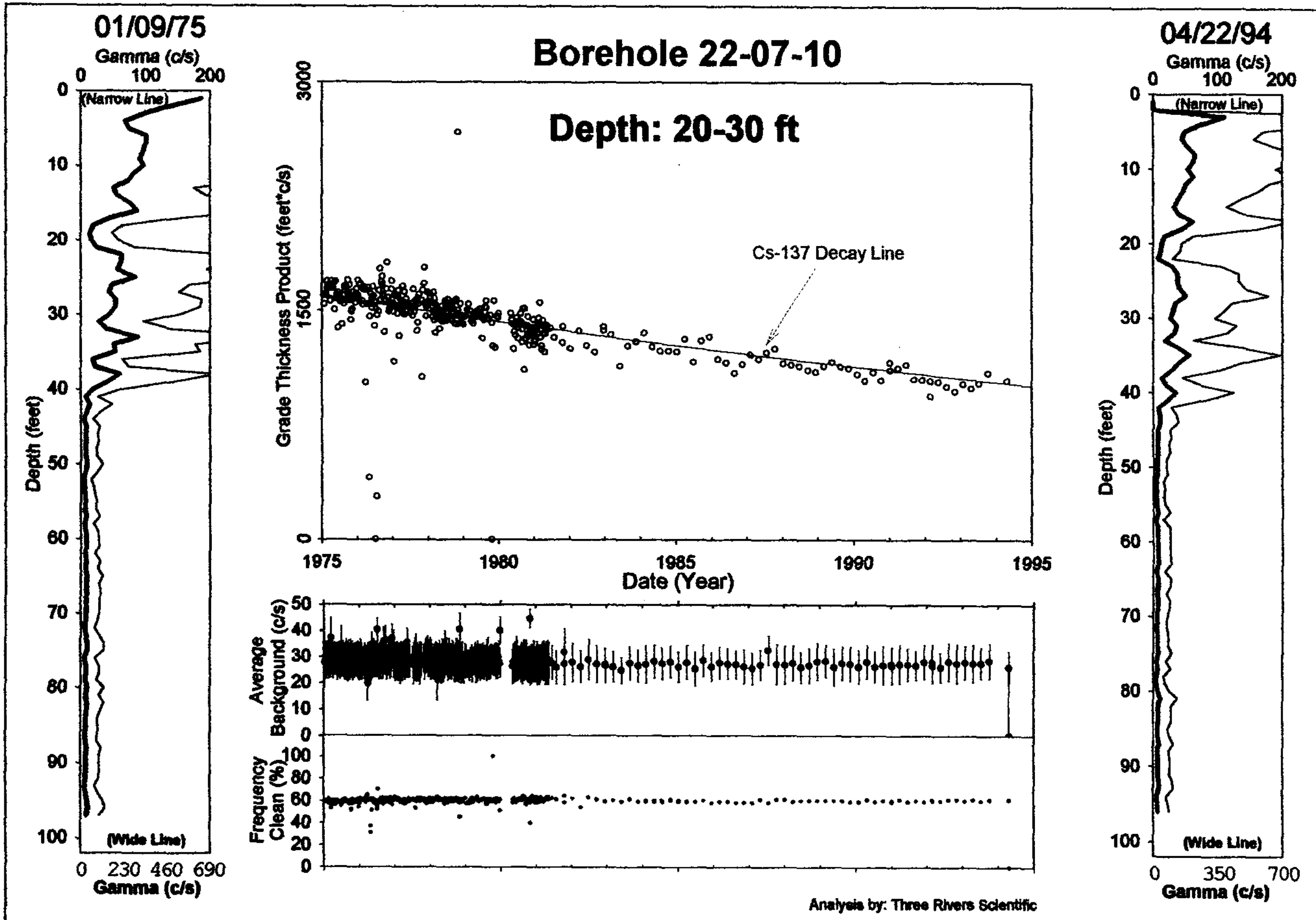


01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Borehole 22-07-10
Depth: 6-12 ft
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
04/22/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)

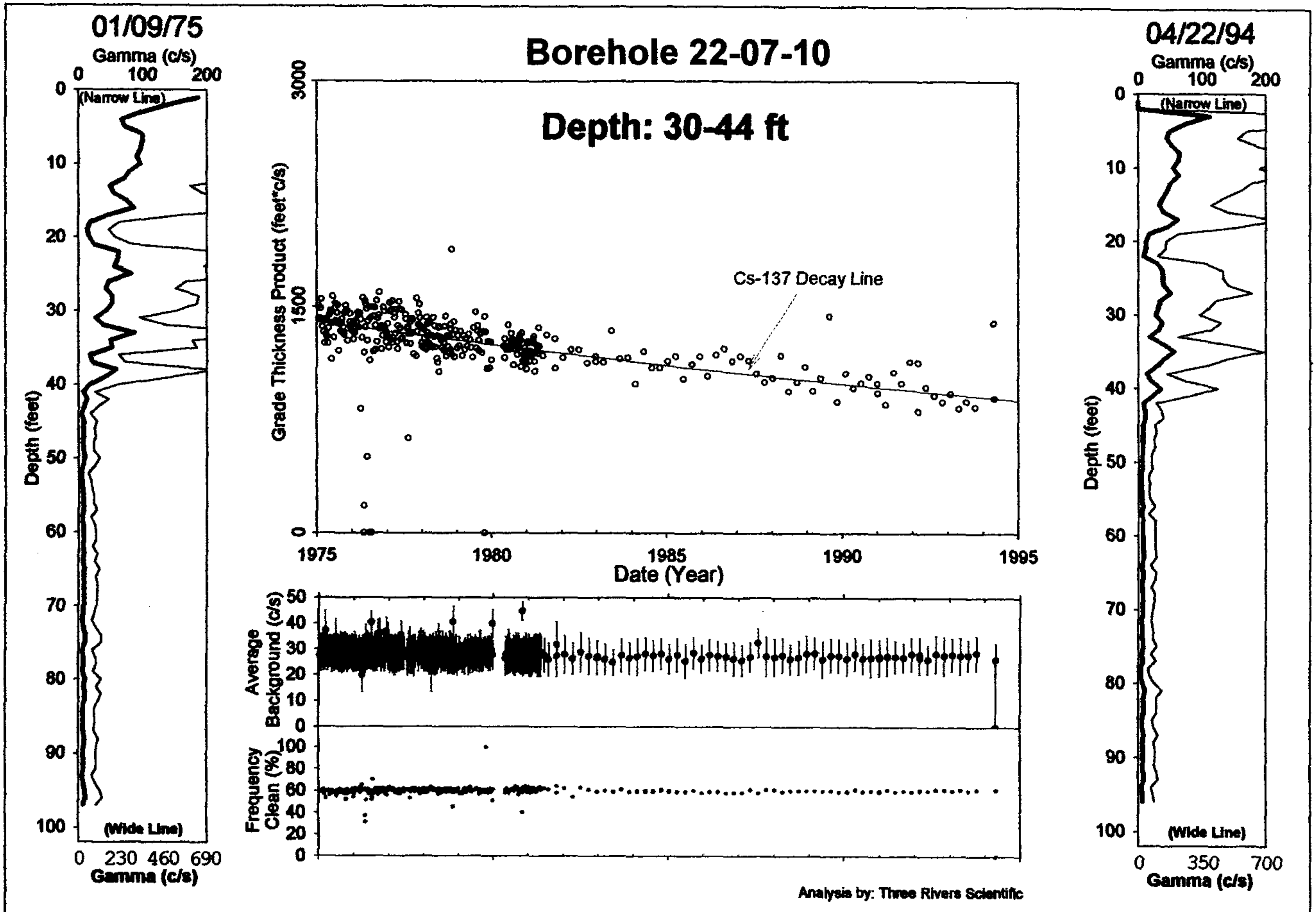


01/09/75
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
(Wide Line)
0 230 460 690
Gamma (c/s)
Borehole 22-07-10
Depth: 12-20 ft
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
04/22/94
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
(Wide Line)
0 350 700
Gamma (c/s)
Analysis by: Three Rivers Scientific

00 337



Borehole 22-07-10
Depth: 20-30 ft
01/09/75
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
(Wide Line)
0 230 460 690
Gamma (c/s)
Grade Thickness Product (feet*c/s)
0 1500 3000
Cs-137 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
04/22/94
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
(Wide Line)
0 350 700
Gamma (c/s)



00 339

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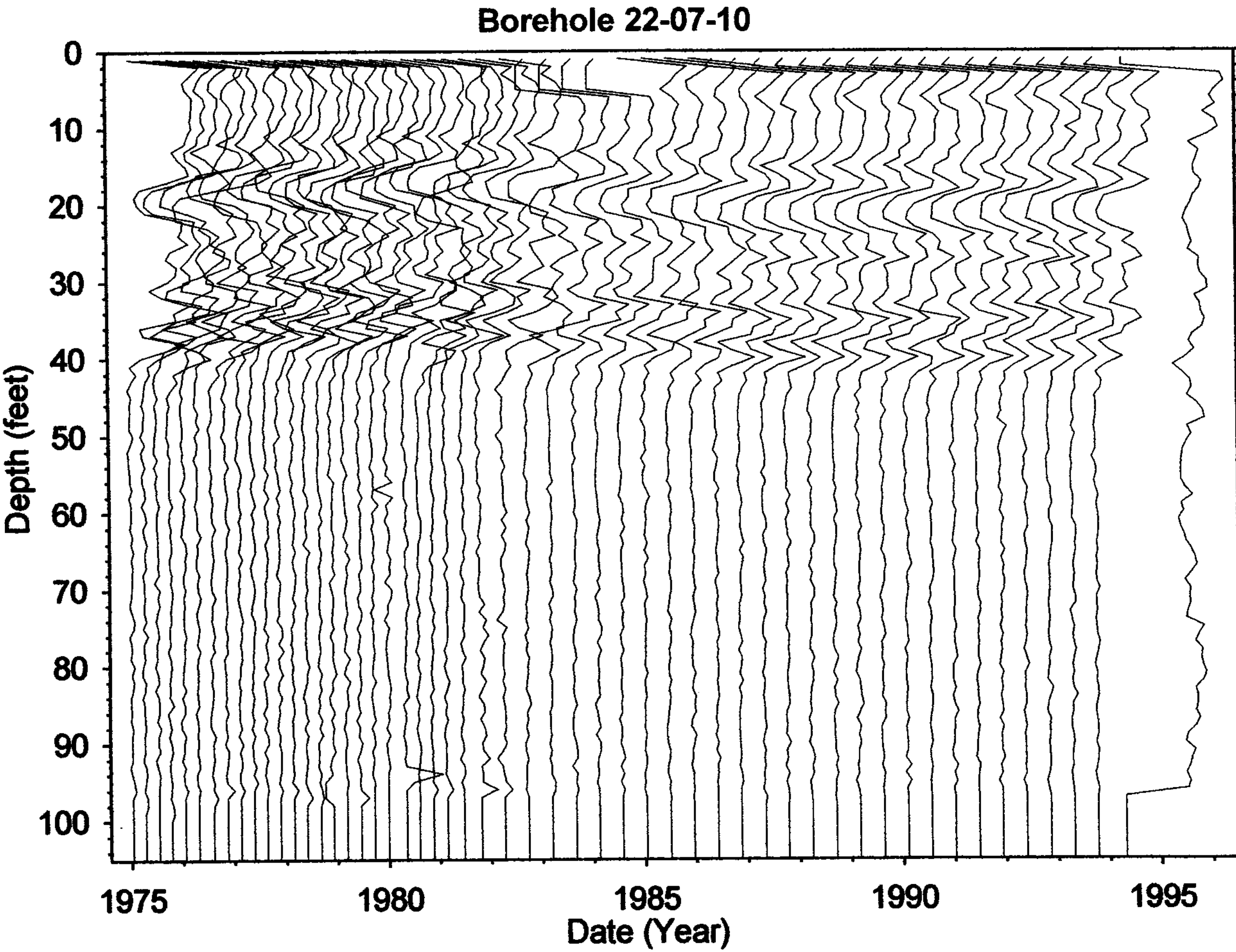
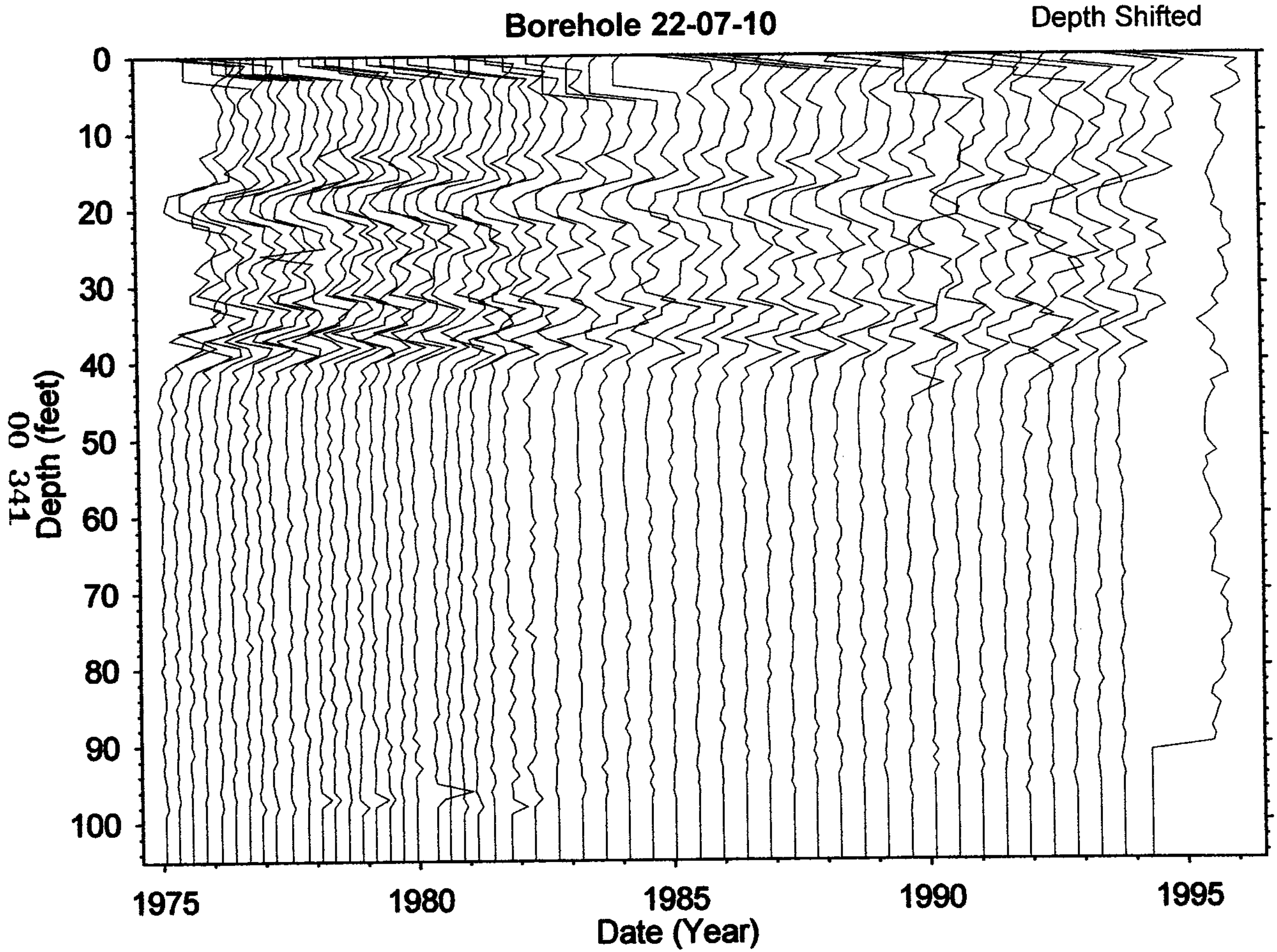


HNF-3532 -REV0

0400340


Borehole 22-07-10
Depth Shifted
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
1975
1980
1985
1990
1995
Date (Year)

Dry Well Survey Analysis - Notes

Borehole B Y (22-07-01)
Total # Surveys 249
Probe Type 04
neutron surveys 7
GR Surveys 242
Log Date: 75-01-09 1st
94-04-22 Last
Presentation Plot Dates ________
(If different from 1st & Last)
Isotope from Spectral Survey: ________
Max Survey Depth 100
Contamination Zone Depth(s): 0-10, 40-52, 52-70, 70-92

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-04-29	16	90	
76-09-02	19	95	
78-09-13	25	92	
80-09-18	10	90	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-03-05	NO RAD Zones	170	
76-05-20	TOOL FAIL	95	
77-12-08A	BAD LOC	40	
78-11-01	HI-BKG	100	
80-12-02	NO RAD Zone	100	
94-04-22	TOOL FAIL	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-03-12	AVG BKG	100	42%	38.5	
76-05-20	% CLEAN	97	11%	32.0	
77-12-08	AVG BKG	35	28%	41.8	
78-11-01	% CLEAN	98	21%	44.7	
79-10-03	% CLEAN	98	2%	49.0	
81-05-13	LENGTH	12	58%	37.3	
94-04-20	% CLEAN	97	0%	0.0	

Analysis Notes

num surveys rejected: (0) ZERO   Background = (0~~<val<50~~) 10-40
0-10 FT: TF ACTIVITY
40-52 FT: INCR 1975 TO 1976 THEN RAPID DECR 1976 TO 1980, NON DETECT AFTER 1981
ISOTOPE NOT CONSISTENT W/ CS-137
52-70 FT: STABLE Co-60
70-92 FT: STABLE Co-60

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price   S/W ver (TFGROSS) V2.20

Dry Well Survey Analysis - Notes

Borehole B4(22-07-02) Total # Surveys 342 Probe Type 04
neutron surveys 6 # GR Surveys 336
Log Date: 75-01-09 1st 94-04-22 Last Presentation Plot Dates ______
(If different from 1st & Last)
Isotope from Spectral Survey: ______ Max Survey Depth 97
Contamination Zone Depth(s): 6-20, 42-53, 53-70, 70-82, 82-95
42-95 FT

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
75-08-27	14	100	
76-04-29	20	95	
76-09-02	19	90	
79-04-12	98	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
76-05-20	TOOL FAIL	95	
78-11-01	BAD LOG	100	
79-04-23A	BAD LOG	70	
79-10-03	HI BKG	100	
80-12-02	MISS-RAD	95	
94-04-20	TOOL FAIL		

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-03-12	% CLEAN	102	14%	41.3	
76-07-02	% CLEAN	94	29%	42.6	
77-05-05	% CLEAN	100	1%	44.0	
78-11-01	AVG BKG	100	17%	43.8	
79-12-26	AVG BKG	96	32%	41.0	
94-04-20	% CLEAN	99	8%	32.6	

Analysis Notes

num surveys rejected: (0) ZERO Background = (0<val<50) 20-40
STACK PLOT (PRELIM VIEW) INDICATES RAPID DOWNWARD MOVEMENT OF A PLUM FRONT (53-82FT) 1979 TO 1983
~~MOVEMENT IS PROBABLY NOT DOWN THE BOREHOLE.~~
RAPID MOVEMENT FROM 47FT IN 1979 TO 62 FT MAY BE A FLUSHING DOWN THE WELL CASING (OUTSIDE)

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V2.20.

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Dry Well Survey Analysis - Notes

Borehole BY (22-07-05) Total # Surveys 5 Probe Type 04

\# neutron surveys 243 # GR Surveys 238

Log Date: 75-01-09 1st 94-04-22 Last Presentation Plot Dates

(If different from 1st & Last)

Isotope from Spectral Survey: Max Survey Depth 97

Contamination Zone Depth(s): 40-57, 57-65, 65-78, 90-100

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-03-25	94	95	
76-04-29	38	80	
76-07-28	118	160	
79-07-24	18	100	
80-09-18	16	80	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
76-03-10	NO RAD Zone	100	
76-05-20	TOOL FAIL	100	
76-07-28	BAD LOG	80	
78-11-01	HI-BKG	100	
80-10-29	HI-BKG	100	
94-04-20	TOOL FAIL	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-03-12	% CLEAN	99	49%	36.5	
76-03-25	% CLEAN	94	0%	0.0	
76-09-23	AVG BKG	96	58	38.1	
77-02-03	AVG BKG	95	53	38.7	
78-11-01	AVG BKG	95	35	40.0	
94-04-20	% CLEAN	96	12%	32.8	

Analysis Notes

num surveys rejected: (0) ZERO	Background = (0<~~val~~<50) 10-35

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V2.20.

Dry Well Survey Analysis - Notes

Borehole BY(22-07-07) Total # Surveys 227 Probe Type 04
neutron surveys 2 # GR Surveys 225
Log Date: 75-01-09 1st 94-04-22 Last Presentation Plot Dates ______
(If different from 1st & Last)
Isotope from Spectral Survey: ______ Max Survey Depth 100
Contamination Zone Depth(s): 30-54, 80-98

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
77-02-03	15	110	
78-09-14	14	90	
80-09-18	19	85	
85-06-12	22	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
76-02-24	TO 76-03-30		NO RAD ZONE (130 FT)
76-12-07	NO RAD ZONE	100	
77-02-03A	BAD LOG	110	
78-06-08A	SHORT LOG	80	
80-09-03	BAD LOG	40	
94-04-20	TOOL FAIL	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
76-12-01	AVG BKG	98	66%	36.2	
77-02-03	AVG BKG	98	68%	32.5	
79-12-26	AVG BKG	96	71%	41.0	
80-09-03	LENGTH	30	53%	31.4	
94-04-20	% CLEAN	98	0%	0.0	

ZONE 30-54 FT; GTP DECAY CURVE FIT 1/1/1975 = Sb=400 Ru=2000 Cs=20

Analysis Notes

num surveys rejected: (0) ZERO Background = (~~0<val<50~~) 55-80
CHECK GTP (ZONE 55-80 FT W/BKG 10-30 FT)
THEN (10-30 FT GTP) W/BKG = 55-80 FT
; CHECK PRODUCED EXPECTED RESULTS; IF BKG < CLEAN ZONE THEN NO TREND IN LOG SURVEYS W/ TIME,
ZONE 30-54' CHANGED (CS CONC < DETECT THRESHOLD, RU DECAY LINE SHOWS DEV.
ZONE 80-98' CHANGED (Co & Sb DECAY DO NOT FIT TREND OF DATA
Category: (Stable, TF Activity, Undetermined, CHANGED RATIO Sb/Co = 10.06 / 72.04 = 0.14 ON JAN 1995

Analyst Name Randall Price S/W ver (TFGROSS) V2.20

Dry Well Survey Analysis - Notes

Borehole B4(22-07-09) Total # Surveys 399 Probe Type 04
\# neutron surveys 4 # GR Surveys 393
Log Date: 75-01-09 1st 94-04-22 Last Presentation Plot Dates
(If different from 1st & Last)
Isotope from Spectral Survey: Max Survey Depth 100
Contamination Zone Depth(s): 0-9, 9-17, 17-36, 62-74, 74-84, 84-94, 94-100

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-04-29	44	90	
76-07-28	30	60	
78-09-14	18	90	
80-09-18	14	90	
84-08-10	30	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-01-29	BAD LOG	170	
75-05-02	BAD LOG	170	
80-06-18	TOOL FAIL	105	
83-06-15	BAD LOG	100	
84-08-10	BAD LOG	100	
94-04-20	TOOL FAIL	100	
77-02-03	TOOL FAIL	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
76-04-29	% CLEAN	91	31%	26.2	
77-02-03	% CLEAN	98	0%	0.0	
78-11-01	AVG BKG	97	34%	42.0	
79-12-26	AVG BKG	96	47%	42.0	
80-10-29	% CLEAN	99	21%	47.1	
81-01-14	% CLEAN	81	38%	30.1	
85-01-23	% CLEAN	99	39%	30.3	
94-04-20	% CLEAN	98	0%	0.0	

Analysis Notes

num surveys rejected: (0) ZERO Background = (0<val<50) 40-60
ZONE 62-74' GTP FIT: Cs=150, Sb=1000, Ru=4500 on 1/1/75
ZONE 74-84' GTP FIT: Co=1200, Sb=4000 on 1/1/75 | Co=76, Sb=21 on 1/96 RATIO= .2835/.70

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V2.20

filein := "GTP62-74.txt" **Well 22-07-09**

A := READPRN(filein) $yr := A^{\langle 1 \rangle}$ $net := A^{\langle 7 \rangle}$ $bkg := A^{\langle 6 \rangle}$ $max := A^{\langle 4 \rangle}$

N := last(yr) N = 291 i := 0 .. N k := 0 .. 300 j := 0 .. 299

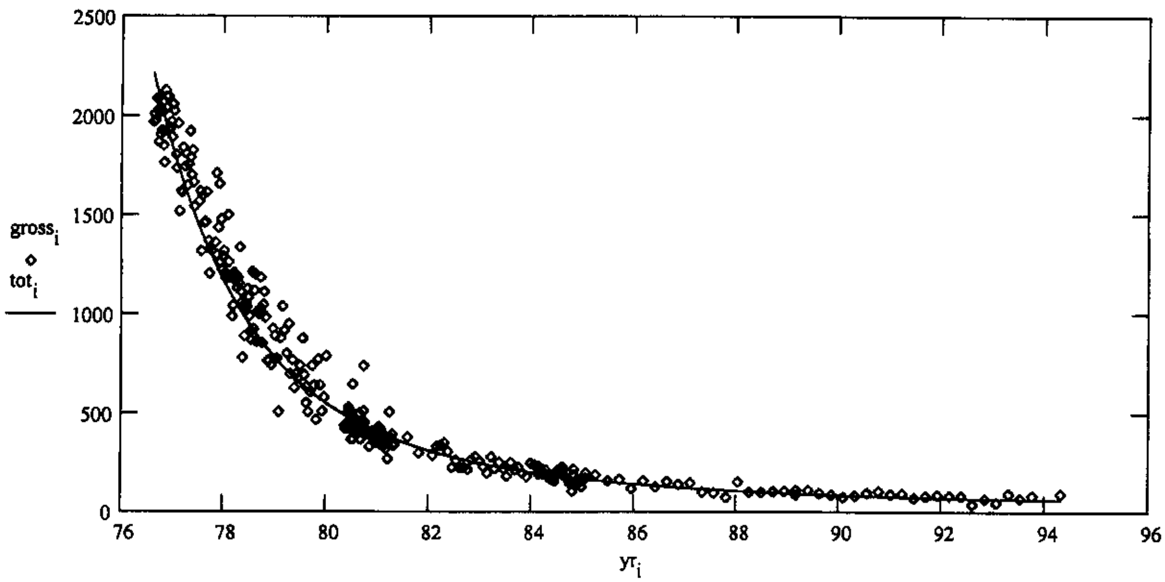
$\tau cs := 30.17$ $\tau co := 2.77$ $\tau eu := 1.02$ Co variables are Sb-125

acs := 80 aco := 1200 aeu := 4000 Eu variables are Ru

$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1$ $tot_i := Cs_i + Eu_i + Co_i$

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1,a3,a2) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + \left[a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} + a2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \right]\right]\right]^2$$

Given

ssq(acs, aeu, aco) = 0 1 = 1 2 = 2

$$\begin{bmatrix} \alpha cs \\ \alpha eu \\ \alpha co \end{bmatrix} := Minerr(acs, aeu, aco)$$

$\alpha cs = 57.073$ Cs-137 $\alpha eu = 3.6 \cdot 10^3$ Ru-106 $\alpha co = 1.484 \cdot 10^3$ Sb-125

$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}}$ $Co_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $\frac{\alpha cs}{\alpha eu} = 0.016$

$tot_i := Cs_i + Eu_i + Co_i$ $\frac{Eu_N}{Cs_N} = 1.969 \cdot 10^{-4}$

$out^{\langle 0 \rangle} := yr$ $out^{\langle 1 \rangle} := tot$ WRITEPRN("twop44-52.txt") := out

Well 22-07-09

filein := "GTP74-84.txt"

A := READPRN(filein) $\quad yr := A^{\langle 1 \rangle} \quad net := A^{\langle 7 \rangle} \quad bkg := A^{\langle 6 \rangle} \quad max := A^{\langle 4 \rangle}$

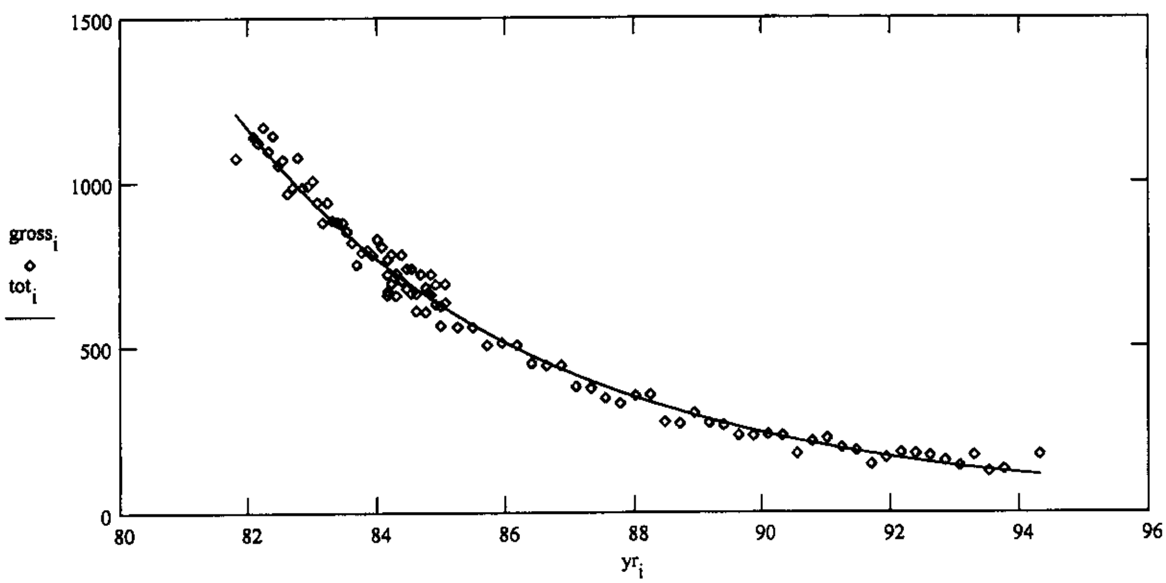
$N := \mathrm{last}(yr) \quad N = 96 \quad i := 0..N \quad k := 0..300 \quad j := 0..299$

1st Isotope is Co (5.27 yrs) $\quad \tau co := 5.27 \quad aco := 1000$

2nd Isotope is Sb (2.77 yrs) $\quad \tau 2 := 2.77 \quad a2 := 4400$

$Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \quad X2_i := a2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}} \quad tot_i := Co_i + X2_i$

$gross_i := net_i$ $\quad$ This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}} \right] \right]^2$$

Given

$ssq(aco,a2) = 0 \quad 1 = 1$

$$\begin{bmatrix} \alpha co \\ \alpha 2 \end{bmatrix} := \mathrm{Minerr}(aco,a2)$$

$\alpha co = 1 \cdot 10^3$ Co-60 $\quad \alpha 2 = 4.405 \cdot 10^3$ Sb-125 $\quad \frac{\alpha co}{\alpha 2} = 0.227$

$Co_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \quad X2_i := \alpha 2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}} \quad tot_i := Co_i + X2_i$

$out^{\langle 0 \rangle} := yr \quad out^{\langle 1 \rangle} := tot \quad$ WRITEPRN("twop.txt") := out $\quad$ Ratio Co/Sb $\frac{Co_N}{X2_N} = 2.246$

Dry Well Survey Analysis - Notes

Borehole BY(22-07-10) Total # Surveys 360 Probe Type 04
neutron surveys 4 # GR Surveys 356
Log Date: 75-01-09 1st 94-04-22 Last Presentation Plot Dates
(If different from 1st & Last)
Isotope from Spectral Survey: Max Survey Depth 97
Contamination Zone Depth(s): 0-6, 6-12, 12-20, 20-30, 30-44

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
75-12-24	10	98	
76-04-29	43	90	
80-09-18	11	95	
85-04-03	15	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
76-04-29	BAD LOG	90	
76-07-02	BAD LOG	90	
77-08-04	TOOL FAIL	100	
78-11-01	TOOL FAIL	100	
79-10-07	BAD LOG	40	
94-04-20	TOOL FAIL	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-03-12	AVG BKG	99	53%	37.2	
76-04-29	%CLEAN	91	37%	29.9	
76-07-02	AVG BKG	92	54%	40.4	
77-05-05	AVG BKG	95	58%	35.5	
78-11-01	AVG BKG	96	45%	40.6	
79-12-26	AVG BKG	93	51%	40.0	
80-10-29	AVG BKG	95	40%	44.7	
94-04-20	%CLEAN	96	0%	0.0	

Analysis Notes

num surveys rejected: (0) ZERO Background = (~~0<val<50~~) 45 - 70

WORK ON DEPTH SHIFT

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V2.20 .

Borehole 22-08-01

Contamination (Cs-137) from 0-12 feet is Tank Farm Activity
Contamination (Co-60 & Sb-125) from 22-32 feet is Stable
Contamination (Co-60 & Sb-125) from 32-42 feet is Stable
Contamination (Co-60 & Sb-125) from 42-59 feet is Stable
Contamination (Co-60 & Sb-125) from 59-82 feet is UNSTABLE
Contamination (Co-60 & Sb-125) from 82-95 feet is UNSTABLE

Grade Thickness Product from 0 to 10 feet is erratic from 1975 through 1986, and is categorized as Tank Farm activity. Grade Thickness Product from 1986 through 1994 is decreasing within observed systematic limitations at a rate consistent with Cs-137 (identified from HPGe detector). The gross gamma activity is at the 30,000 counts per second rate, which may be beyond the linear region of the counting system.

Grade Thickness Product for three radioactive zones (22-32, 32-42, 42-59 feet) is decreasing within the gross gamma sensitivity to each isotope and relative intensity at a rate consistent with a least squares fit of Sb-125 (hypothesis) and Co-60 (identified from HPGe detector) from 1975 through 1994. The least squares fit results in a gross gamma contribution ratio for Sb-125 to Co-60 of 0.7, 0.1, and 0.3, respectively for each zone, on June, 1994.

Grade Thickness Product for the radioactive zone (59-82 feet) is decreasing at a rate that exceeds the decay of Sb-125 (hypothesis) and Co-60 (identified from HPGe detector) from 1976 to 1979, then is less than the decay rate from 1980 to 1984, and then is consistent with the decay rate from 1985 to 1995. Movement in this zone is unclear on the stack plot. The least squares fit results in a gross gamma contribution ratio for Sb-125 to Co-60 of 0.04 on June 1994.

Grade Thickness Product for the radioactive zone (82-95 feet) shows the zone is clean until 1982, then from 1982 to 1987 the radioactive contaminant is INCREASING, and begins to decrease at a rate consistent with the decay of Co-60 (identified from HPGe detector) from 1987 to 1995. This can be seen in the stack plot upon close examination.

Grade Thickness Product for the combined radioactive zone (22-95 feet) is decreasing within the gross gamma sensitivity to each isotope and relative intensity at a rate consistent with a least squares fit of Sb-125 (hypothesis) and Co-60 (identified from HPGe detector) from 1975 to 1995. This indicates the contaminants likely entered the subsurface in a single event and the contaminant movement is ongoing redistribution. The least squares fit results in a gross gamma contribution ratio for Sb-125 to Co-60 of 0.14 in 1995.

Borehole 22-08-01

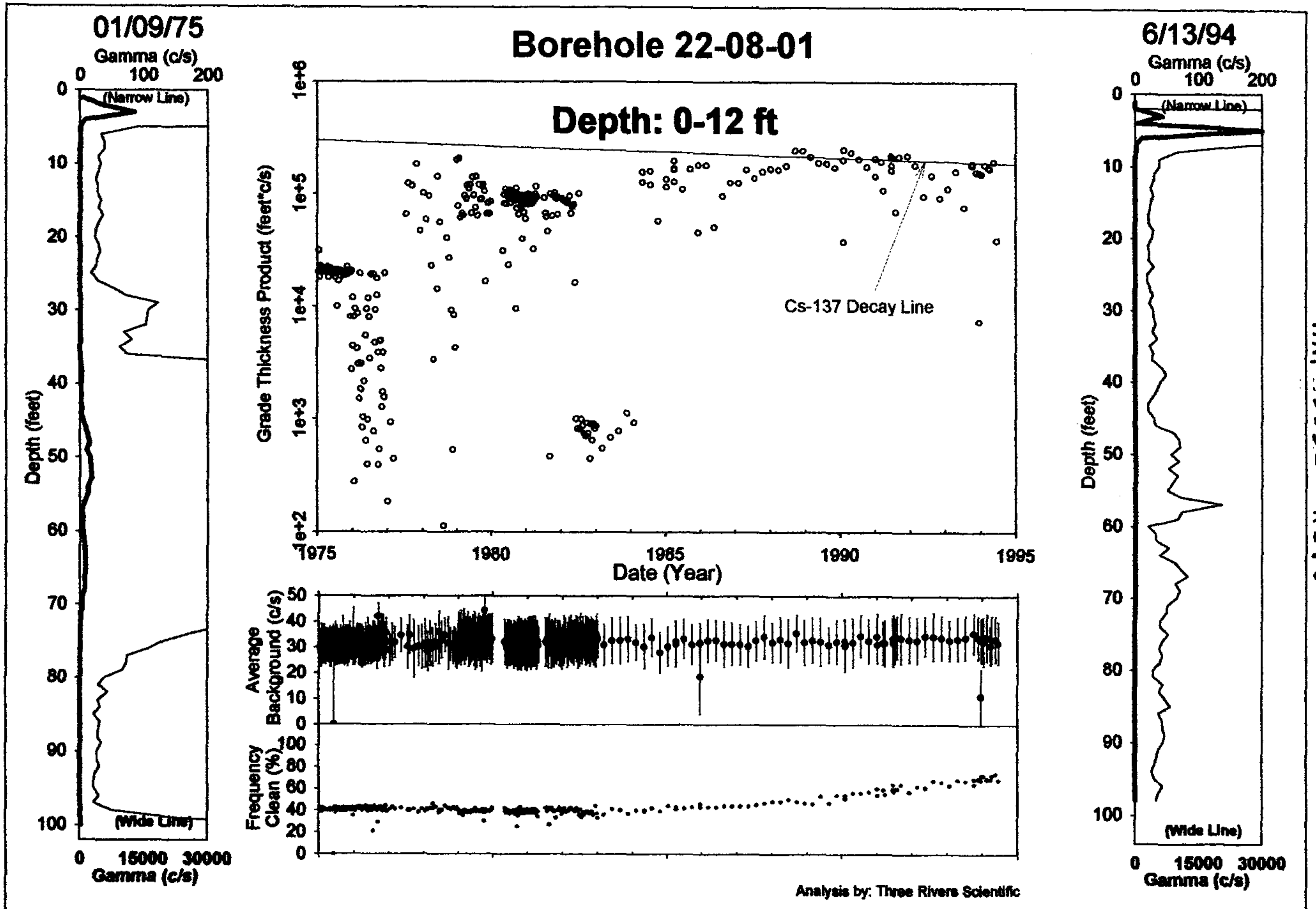
page 2 of 2

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (2 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	6/13/1994
Number Surveys :	312

Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	12 to 22 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-12 feet is TF Activity 22-32, 32-42, 42-59 feet is Stable 59-82, 82-95 feet UNSTABLE
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



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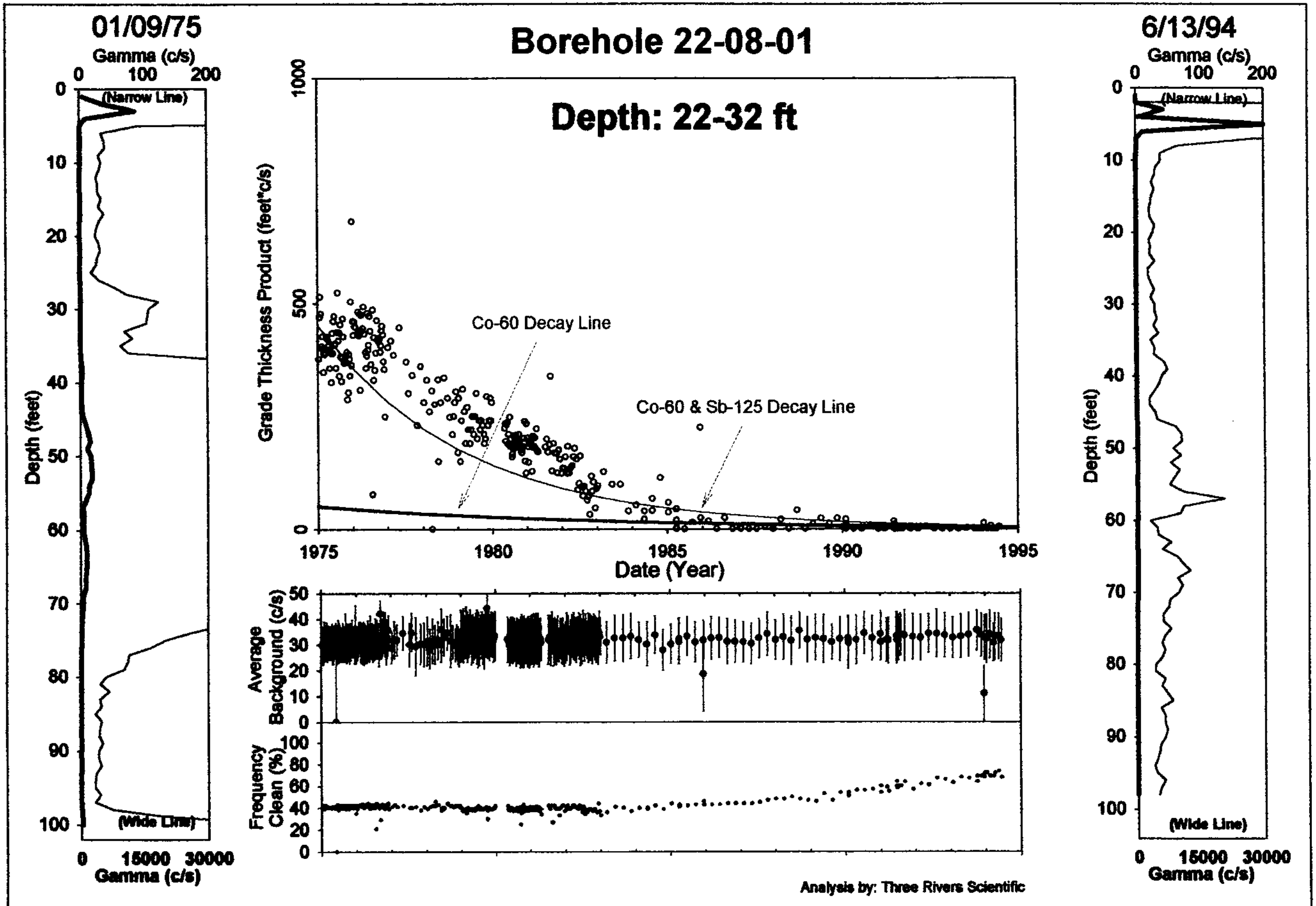
HNF-3532 -REV0



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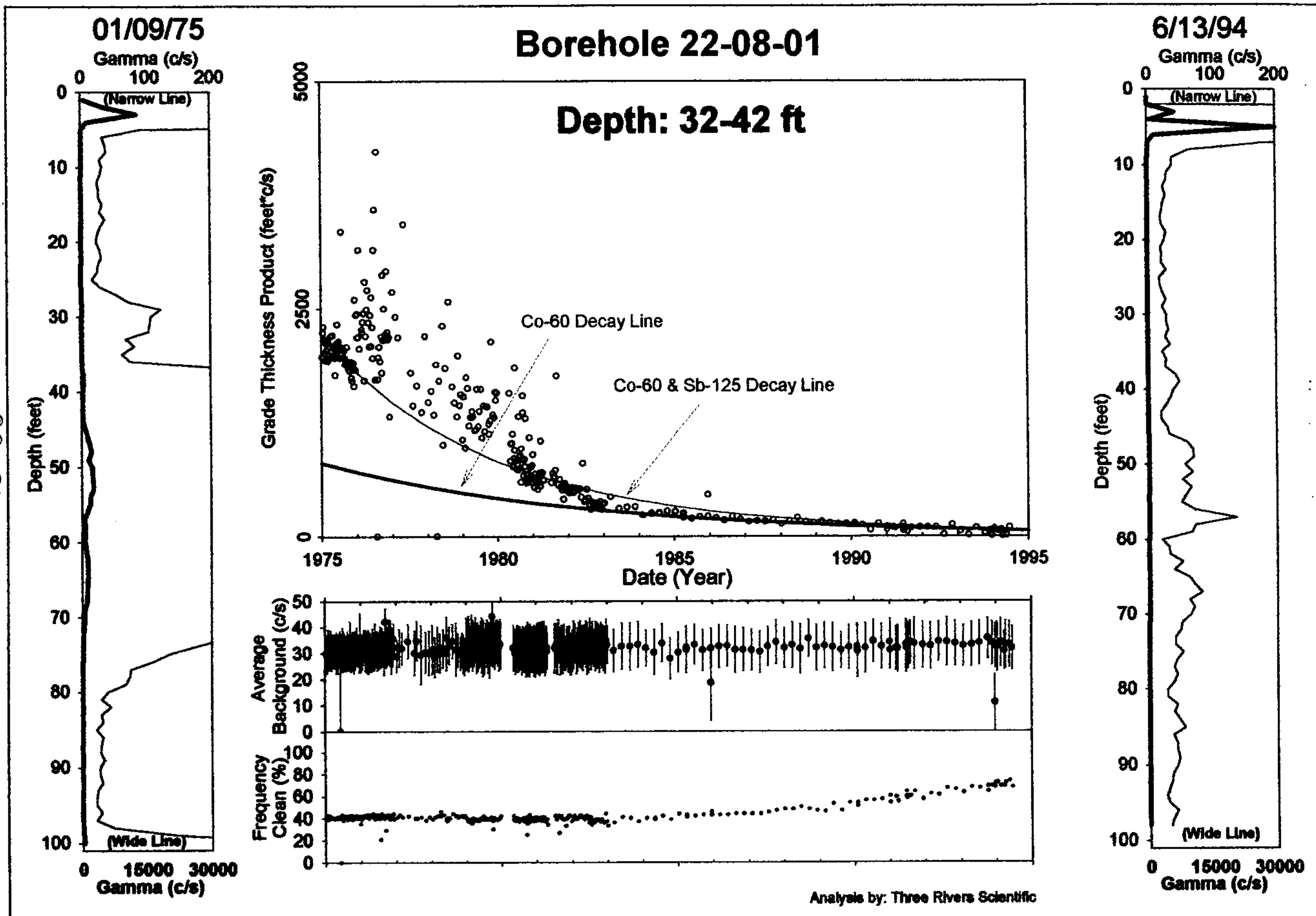
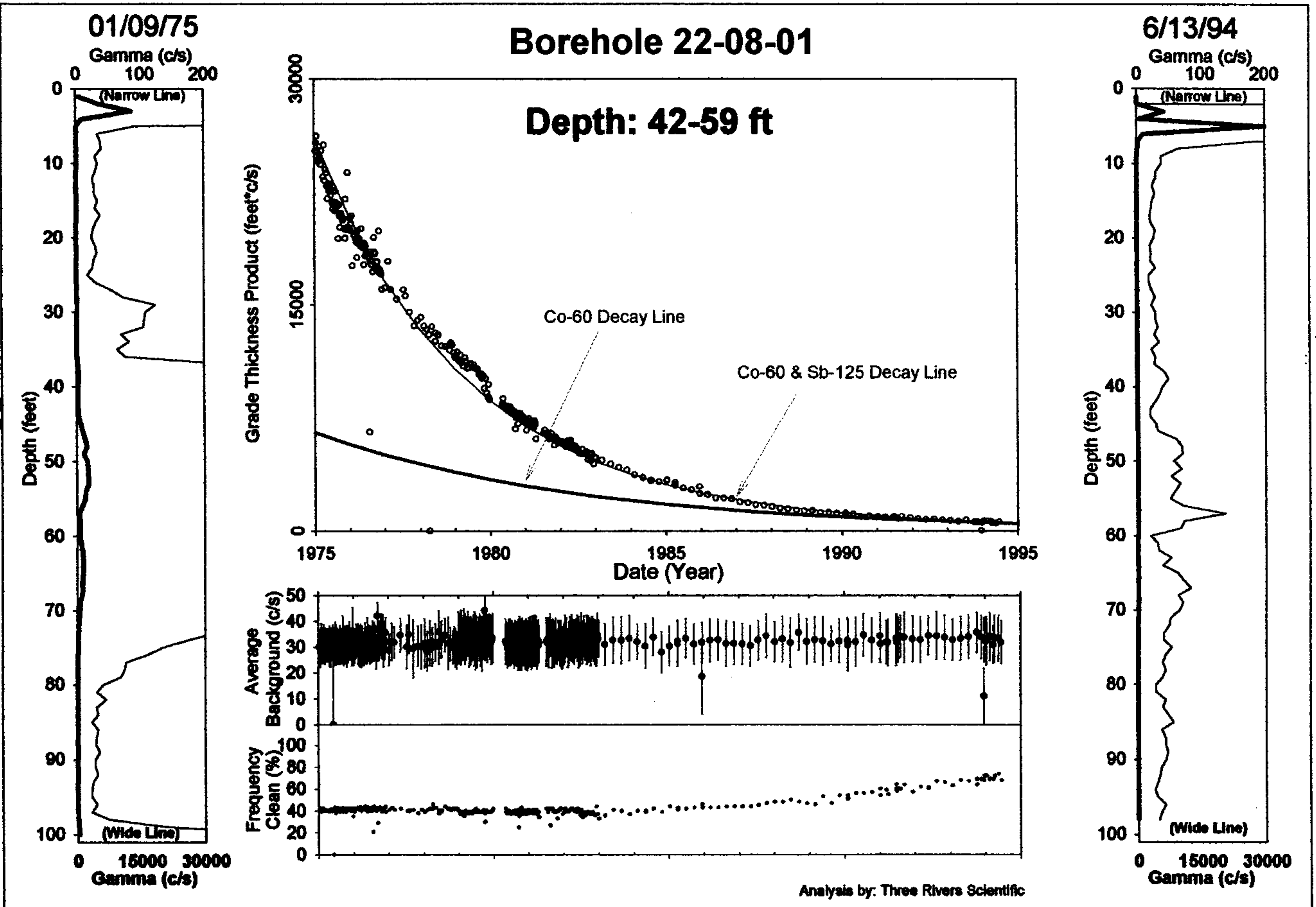
HNF-3532 -REV0


Borehole 22-08-01
Depth: 32-42 ft
01/09/75
6/13/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Co-60 & Sb-125 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific



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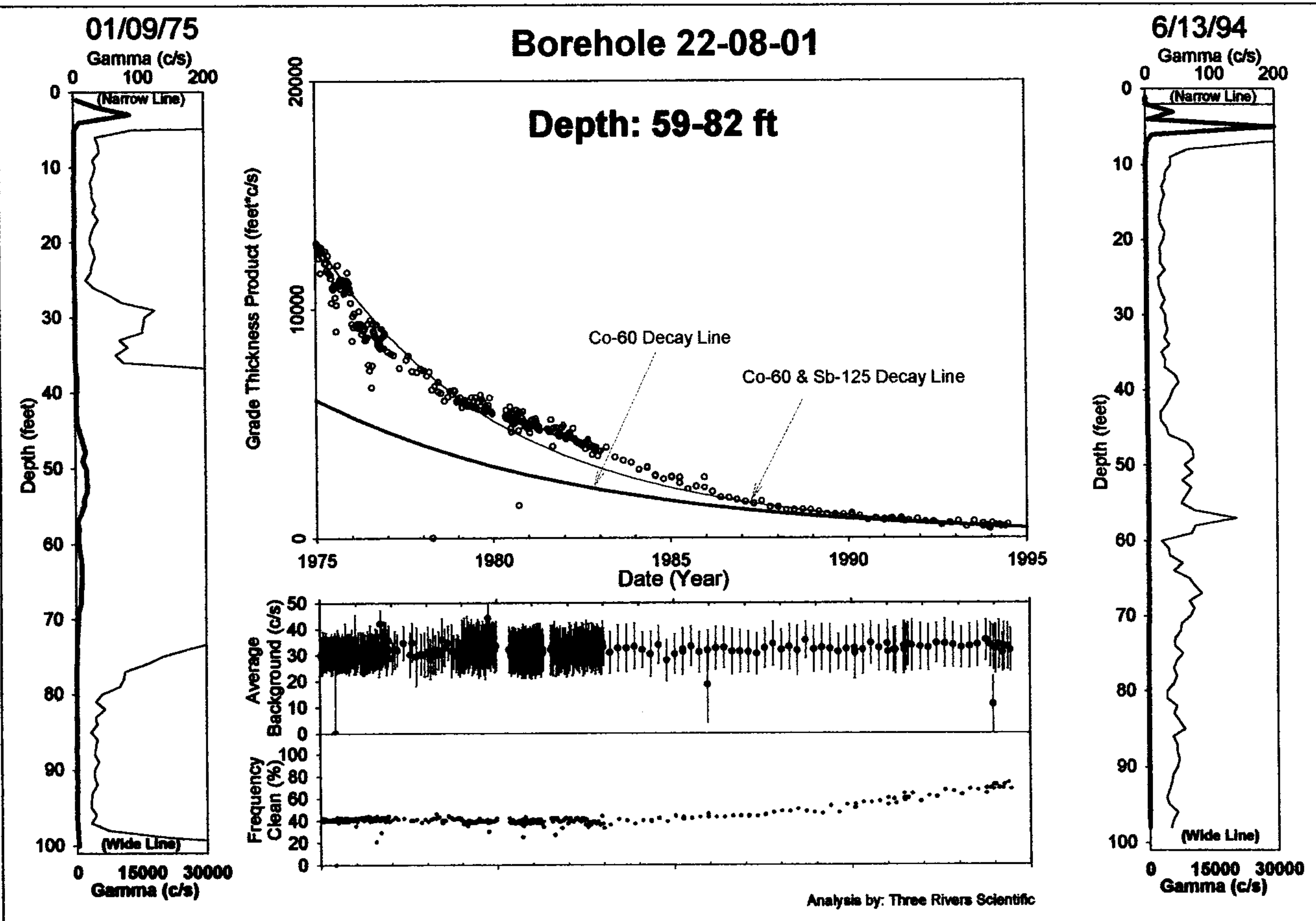
HNF-3532 -REV0



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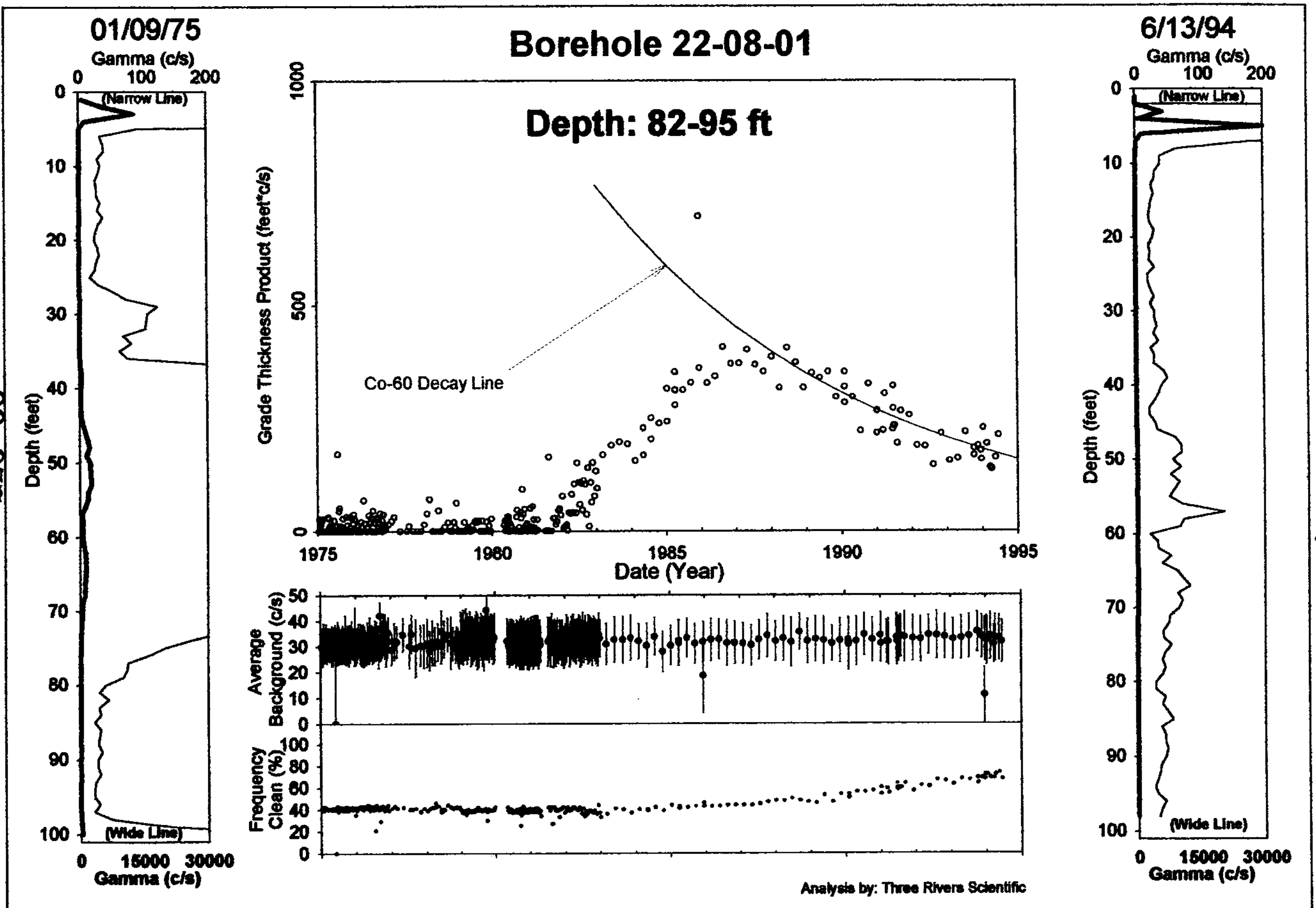
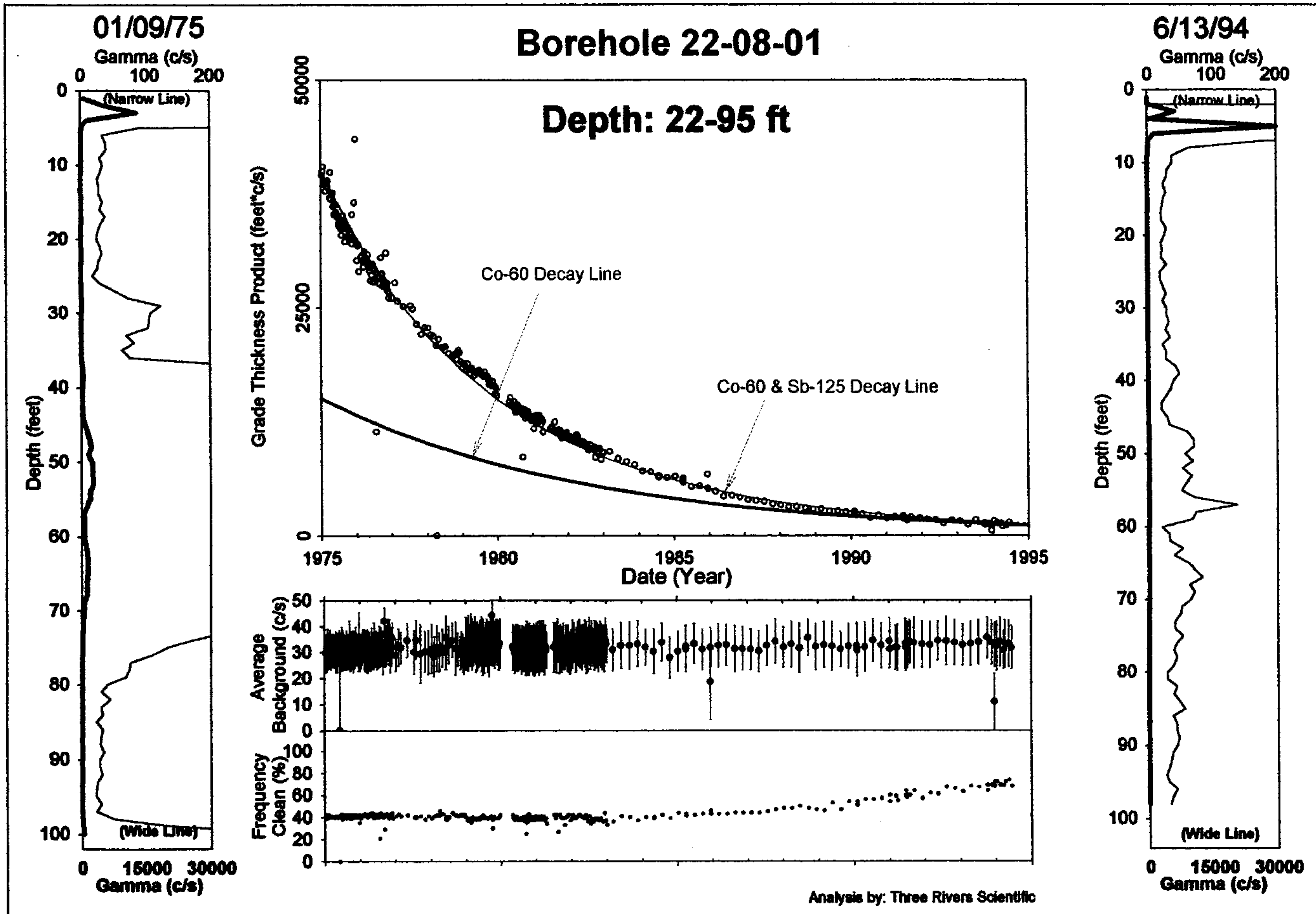
HNF-3532 -REV0



HNF-3532 -REV0

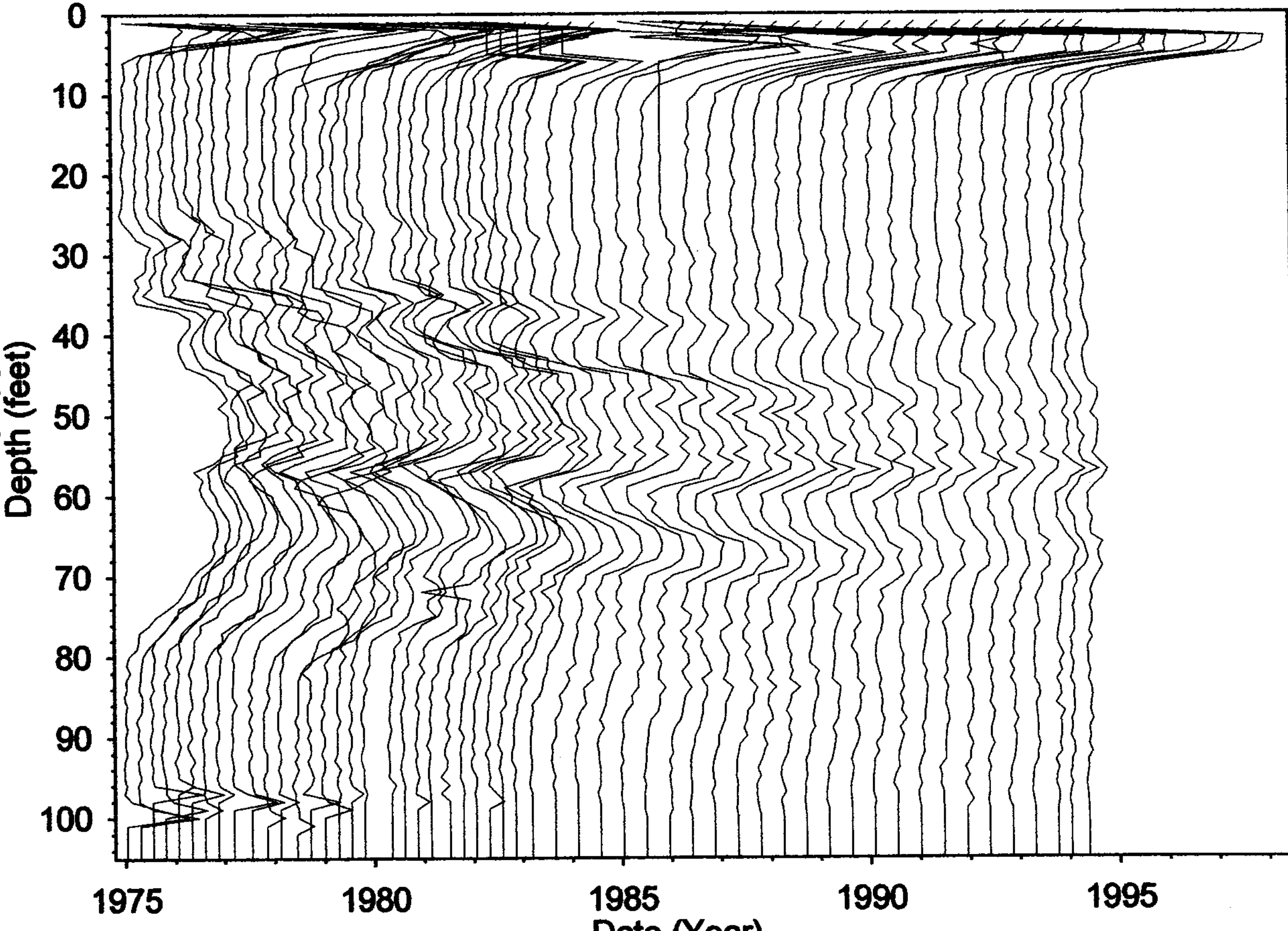
00 357



00 358

HNF-3532 -REV0

Borehole 22-08-01



HNF-3532 -REV0

00 359

Borehole 22-08-02

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity
Contamination (Sb-125) from 20-30 feet is Stable
Contamination (Sb-125) from 44-62 feet is **UNSTABLE**
Contamination (Sb-125) from 62-72 feet is **UNSTABLE**
Contamination (Sb-125) from 72-84 feet is **UNSTABLE**
Contamination (Sb-125) from 84-100 feet is **UNSTABLE**

Grade Thickness Product from 0 to 10 feet is erratic for the 20 years of surveillance monitoring, and is categorized as Tank Farm activity. The decay line for Cs-137 (identified from HPGe detector) is shown but does not agrees with any significant number of surveys.

Grade Thickness Product for the radioactive zone (20-30 feet) is decreasing within the gross gamma sensitivity at a rate consistent with the decay of Sb-125 (hypothesis) between 1975 and 1994.

Grade Thickness Product for the radioactive zone (44-62 feet) is decreasing at a rate from 1975 to 1981 that does not fit the decay of Sb-125 (hypothesis) or Co-60 (identified from HPGe detector). The decay line for Sb-125 is shown as a reference. The stack plot shows that radioactive materials migrated down, out of this zone.

Grade Thickness Product for the radioactive zone (62-72 feet) is INCREASING in 1975 then decreases at a rate from 1977 to 1988 that does not fit the decay of Sb-125 (hypothesis) or Co-60 (identified from HPGe detector). The decay line for Sb-125 is shown as a reference.

Grade Thickness Product for the radioactive zone (72-84 feet) is INCREASING from 1981 to 1985 with decreasing rates the other times (1975-1981 and 1985-1995). The decay line for Co-60 (identified from HPGe detector) is shown as a reference. The stack plot shows that radioactive materials migrated down, through this zone.

Grade Thickness Product for the radioactive zone (84-100 feet) is INCREASING from 1988 to 1991 with decreasing or constant rates the other times (1975-1988 and 1991-1995). The decay line for Co-60 (identified from HPGe detector) is shown as a reference.

Grade Thickness Product of the combined radioactive zone (44-100 feet) is decreasing at a rate that is consistent with a least squares fit of Sb-125 (hypothesis) and Co-60 (identified from HPGe detector) from 1975-1985 and deviates from 1985-1995. The deviation may indicate added contamination in the zone. The least squares fit results in a gross gamma contribution ratio for Sb-125 to Co-60 of 0.1 on June 1994.

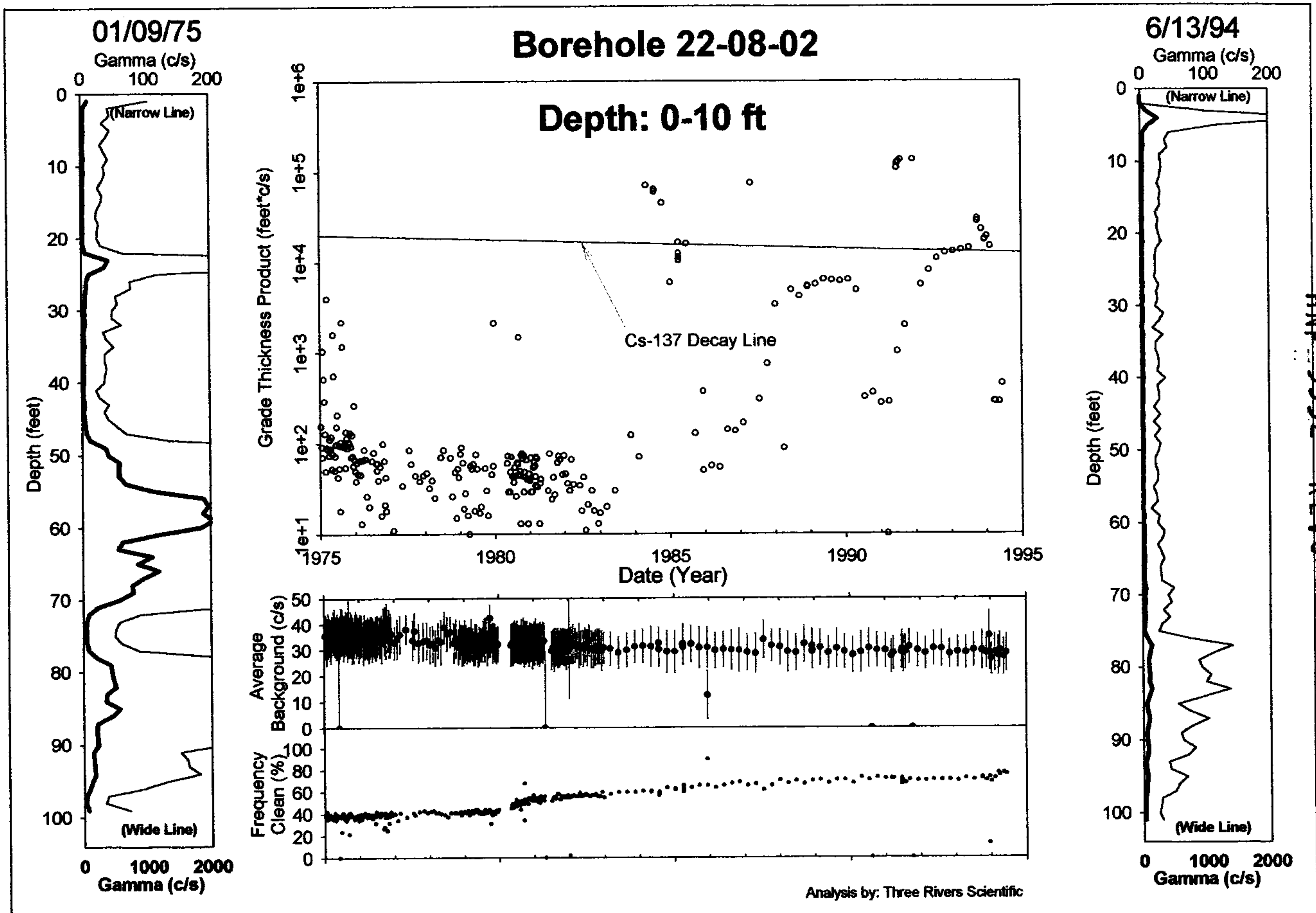
Borehole 22-08-02

Gross Gamma Survey Information

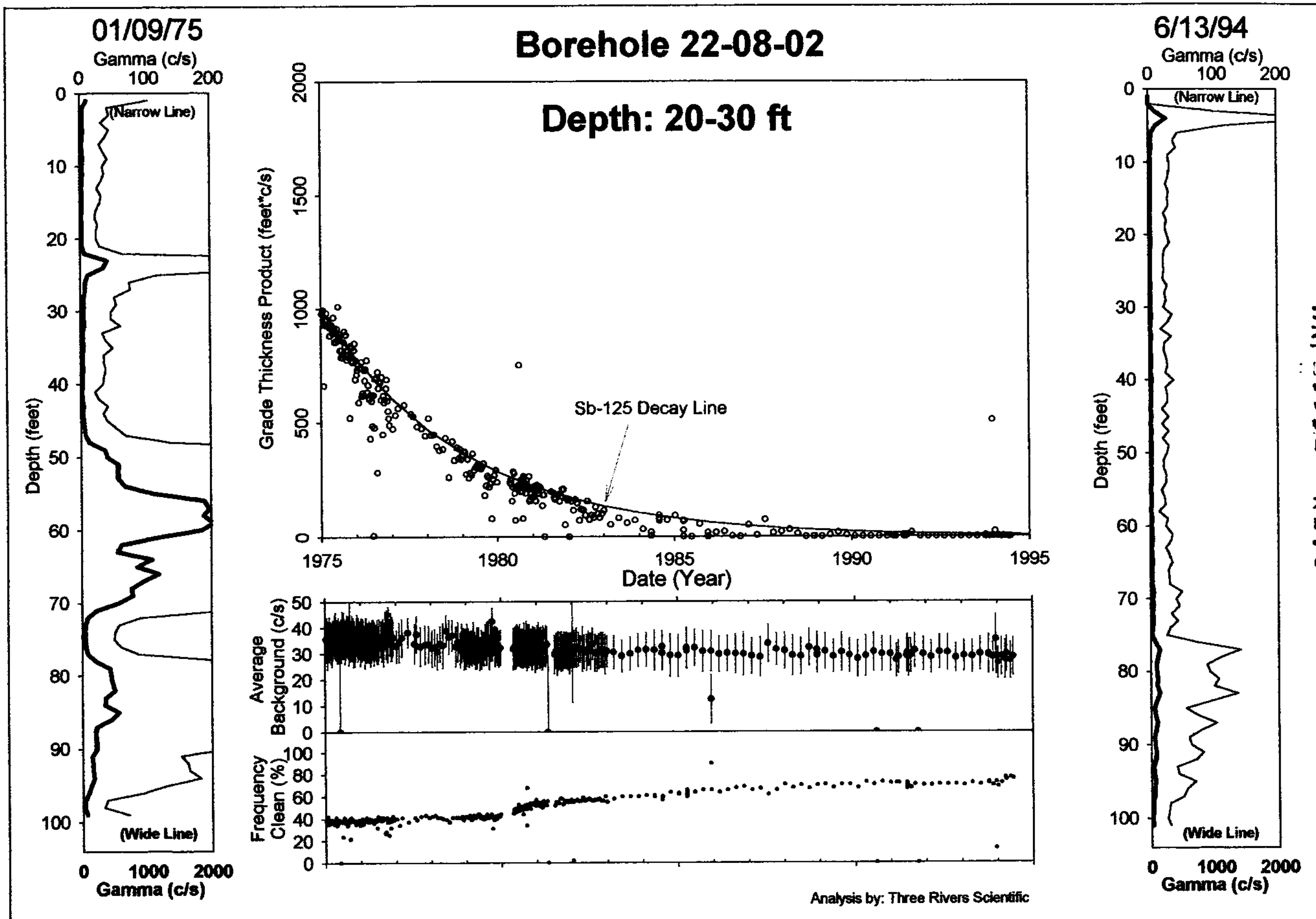
Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (2 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	6/13/1994
Number Surveys :	305

Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	10 to 20 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 feet is TF Activity 20-30 feet is Stable 44-62, 62-72, 72-84, 84-100 are UNSTABLE
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific

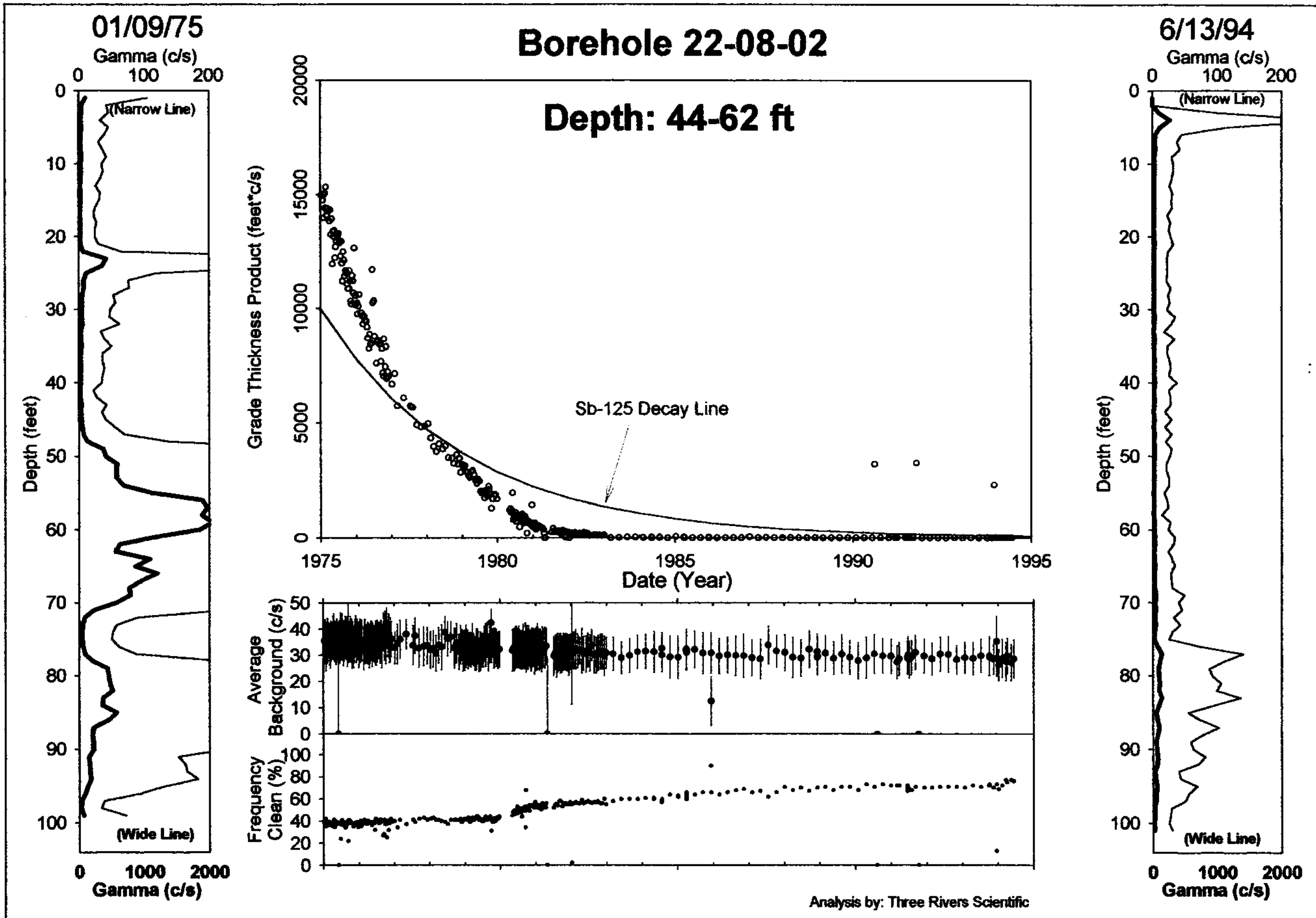


Borehole 22-08-02
Depth: 0-10 ft
01/09/75
6/13/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific

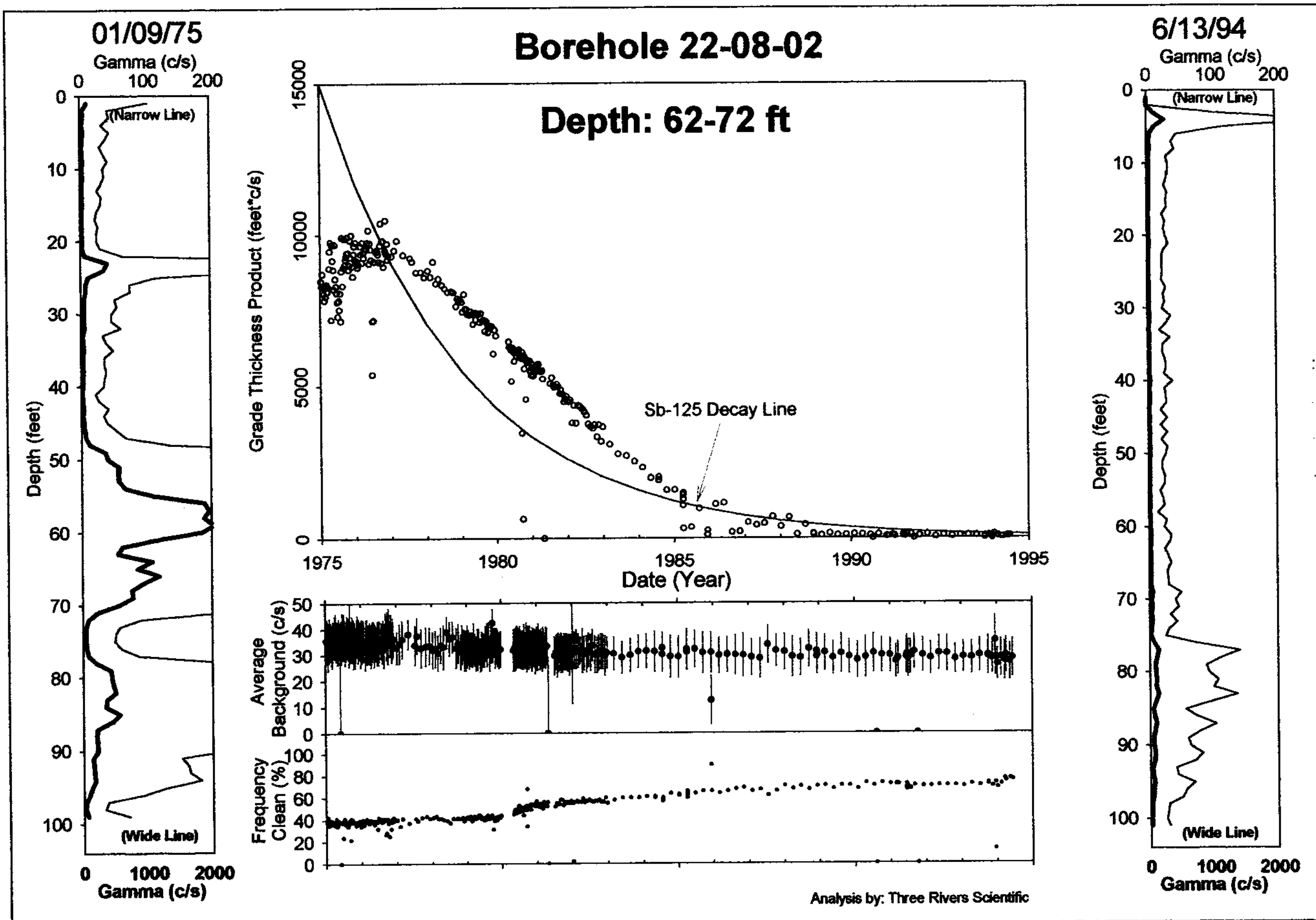


00 363

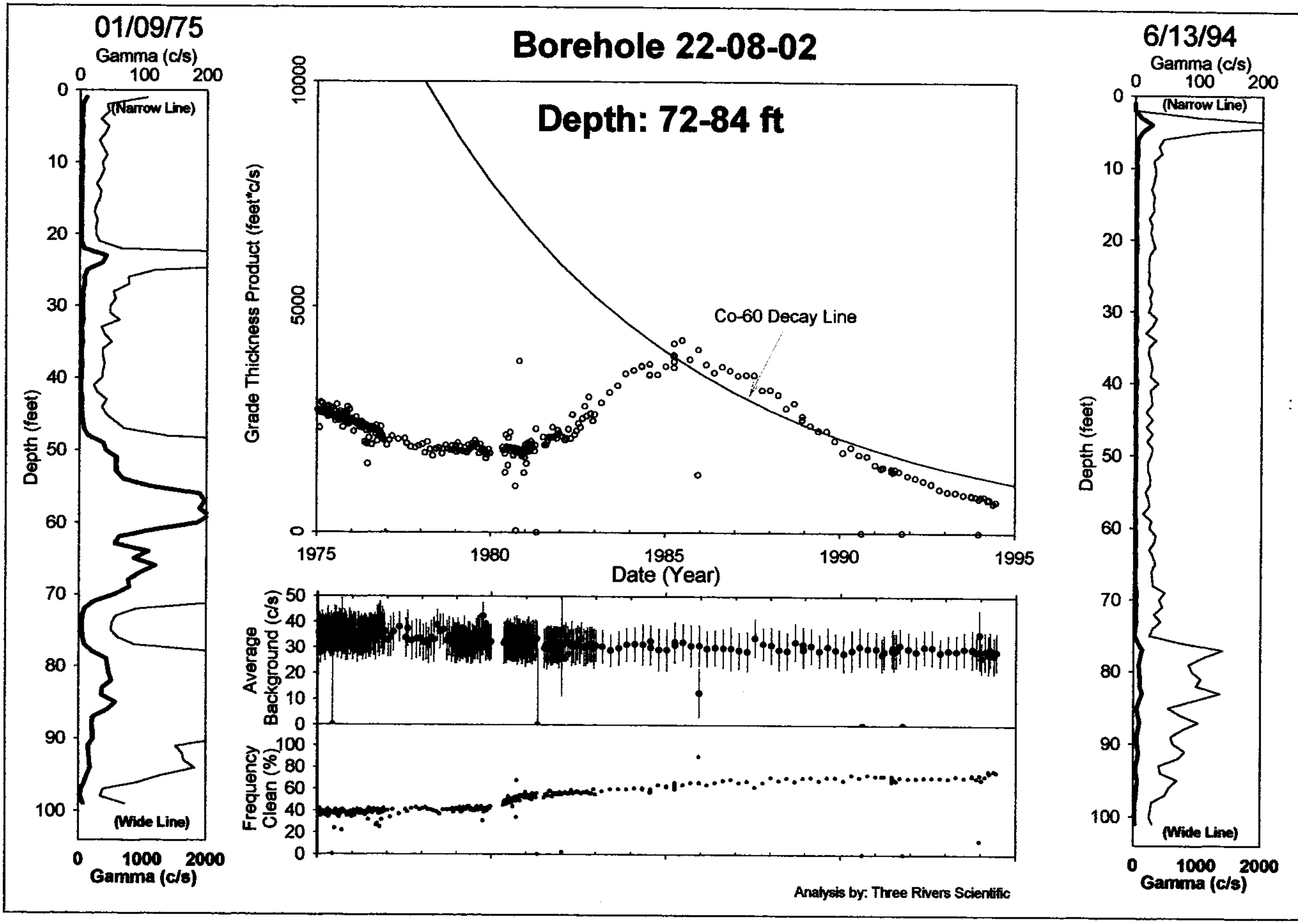
HNF-3532 -REV0



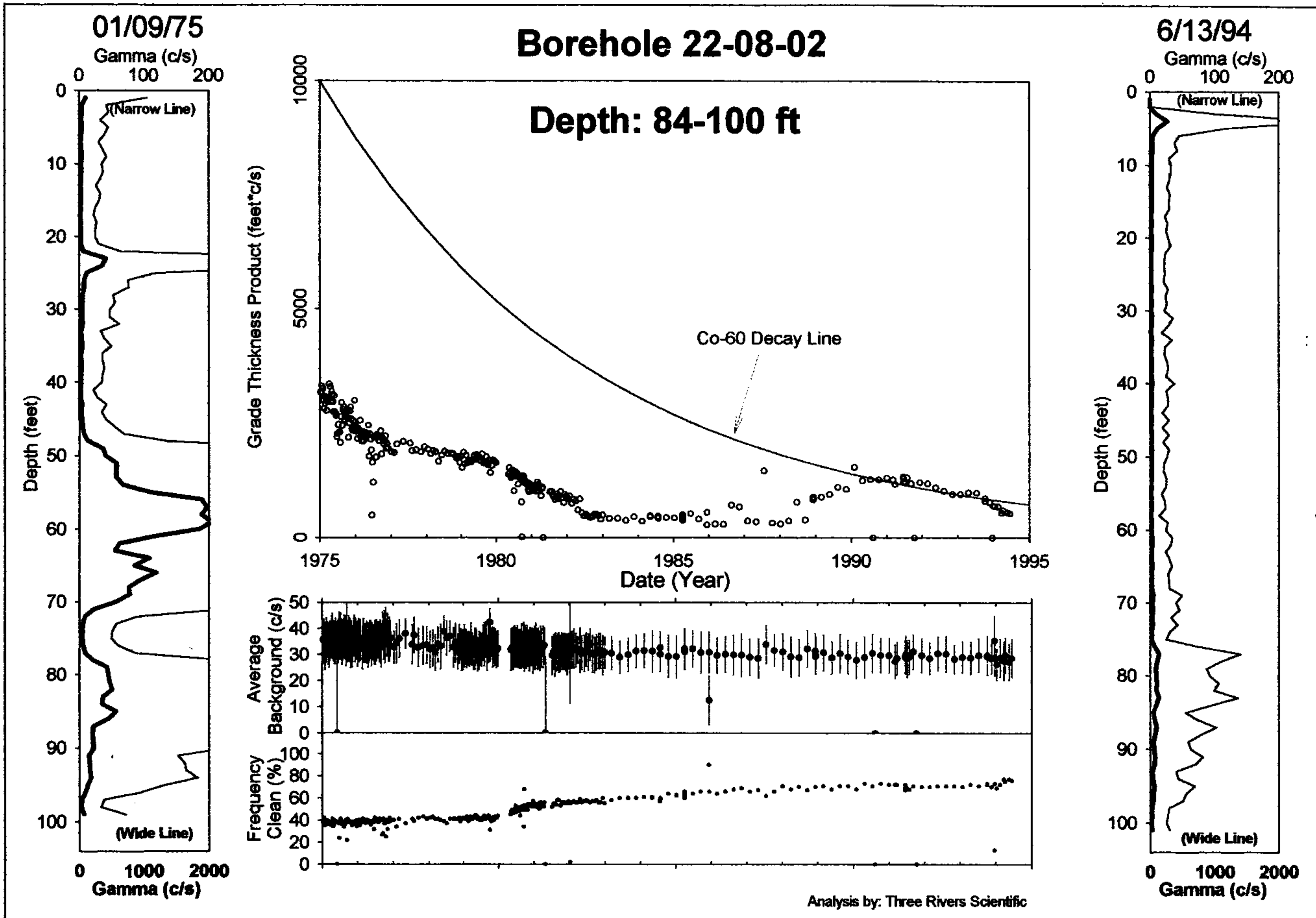
01/09/75
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
(Wide Line)
0 1000 2000
Gamma (c/s)
Borehole 22-08-02
Depth: 44-62 ft
Grade Thickness Product (feet*c/s)
0 5000 10000 15000 20000
Sb-125 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
6/13/94
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
(Wide Line)
0 1000 2000
Gamma (c/s)

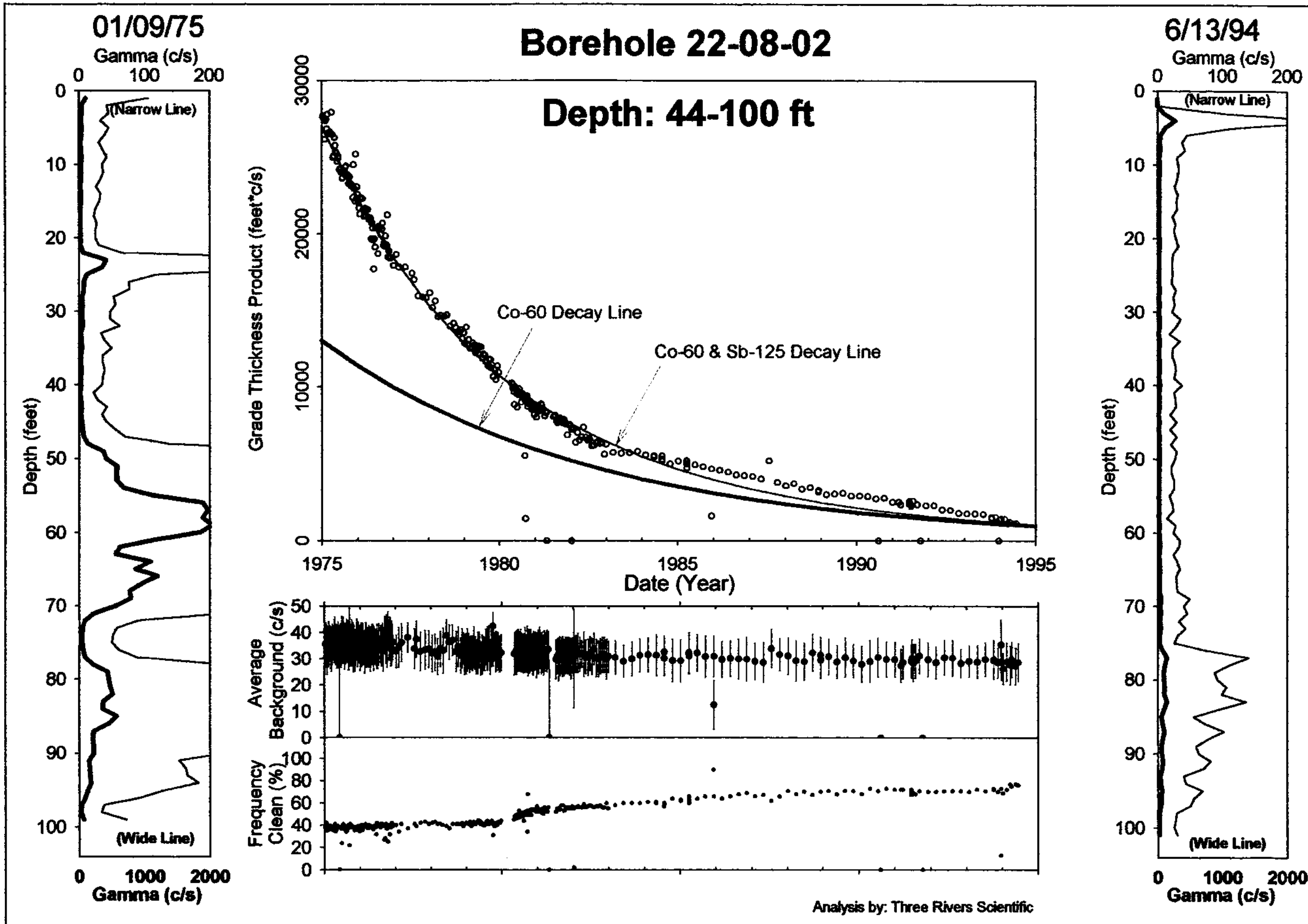

Borehole 22-08-02
Depth: 62-72 ft
01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Sb-125 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
6/13/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)

HNF-3532 - REV 0



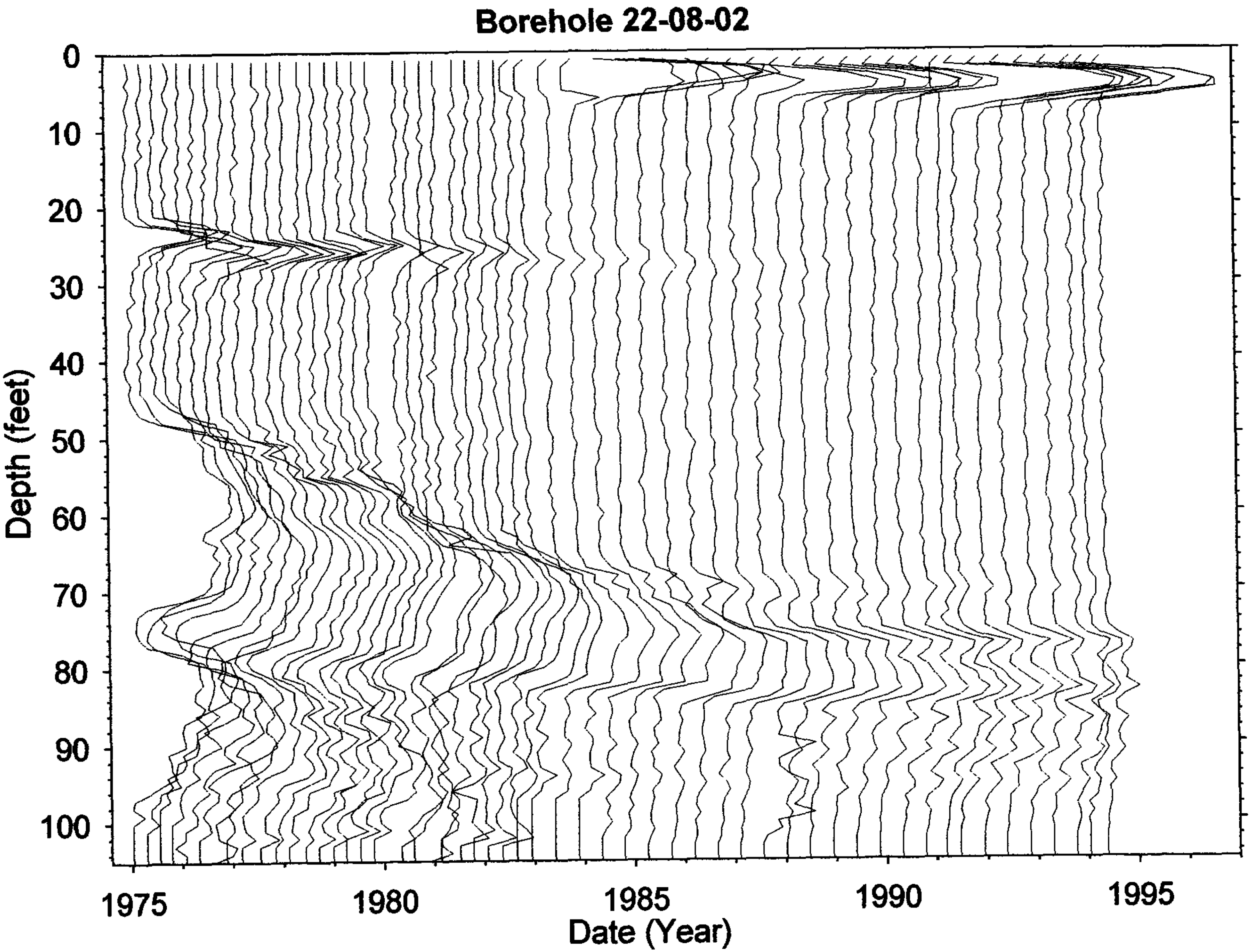
00 366


Borehole 22-08-02
Depth: 84-100 ft
01/09/75
6/13/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific



00 368

HNF-3532 - REV 0



HNF-3532 - REV 0

00 369

Borehole 22-08-05

page 1 of 2

Contamination (Cs-137) from 0 to 8 feet is Tank Farm Activity
Contamination (Co-60) from 36-45 feet is Stable
Contamination (Co-60) from 45-53 feet is Stable
Contamination (Co-60) from 53-63 feet is Stable
Contamination (Co-60) from 63-74 feet is **UNSTABLE** early
Contamination (Co-60) from 74-84 feet is **UNSTABLE**

Grade Thickness Product from 0 to 8 feet is erratic from 1975 through 1986, and is categorized as Tank Farm activity. Grade Thickness Product from 1986 through 1994 is decreasing within counting statistics at a rate consistent with Cs-137 (identified from HPGe detector).

Grade Thickness Product for three radioactive zones (36-45, 45-53, 53-63 feet) is decreasing within observed systematic limitations at a rate consistent with Co-60 *(identified from HPGe detector) from 1975 through 1994.*

Grade Thickness Product for the radioactive zone (63-74 feet) is decreasing at a rate that is significantly less than the decay of Co-60 (identified from HPGe detector) from 1975 to 1986. Then from 1986 to 1995 the decrease in grade thickness product is consistent with the decay rate. The stack plot shows the radioactive contaminants to be migrating deeper in the formation.

Grade Thickness Product for the radioactive zone (74-84 feet) shows the zone is clean until 1985, then from 1985 to 1990 the radioactive contaminant is INCREASING, and begins to decrease at a rate consistent with the decay of Co-60 (identified from HPGe detector) from 1990 to 1995.

Grade Thickness Product for the combined radioactive zone (36-84 feet) is decreasing within the gross gamma sensitivity at a rate consistent with Co-60 (identified from HPGe detector) from 1975 to 1995.

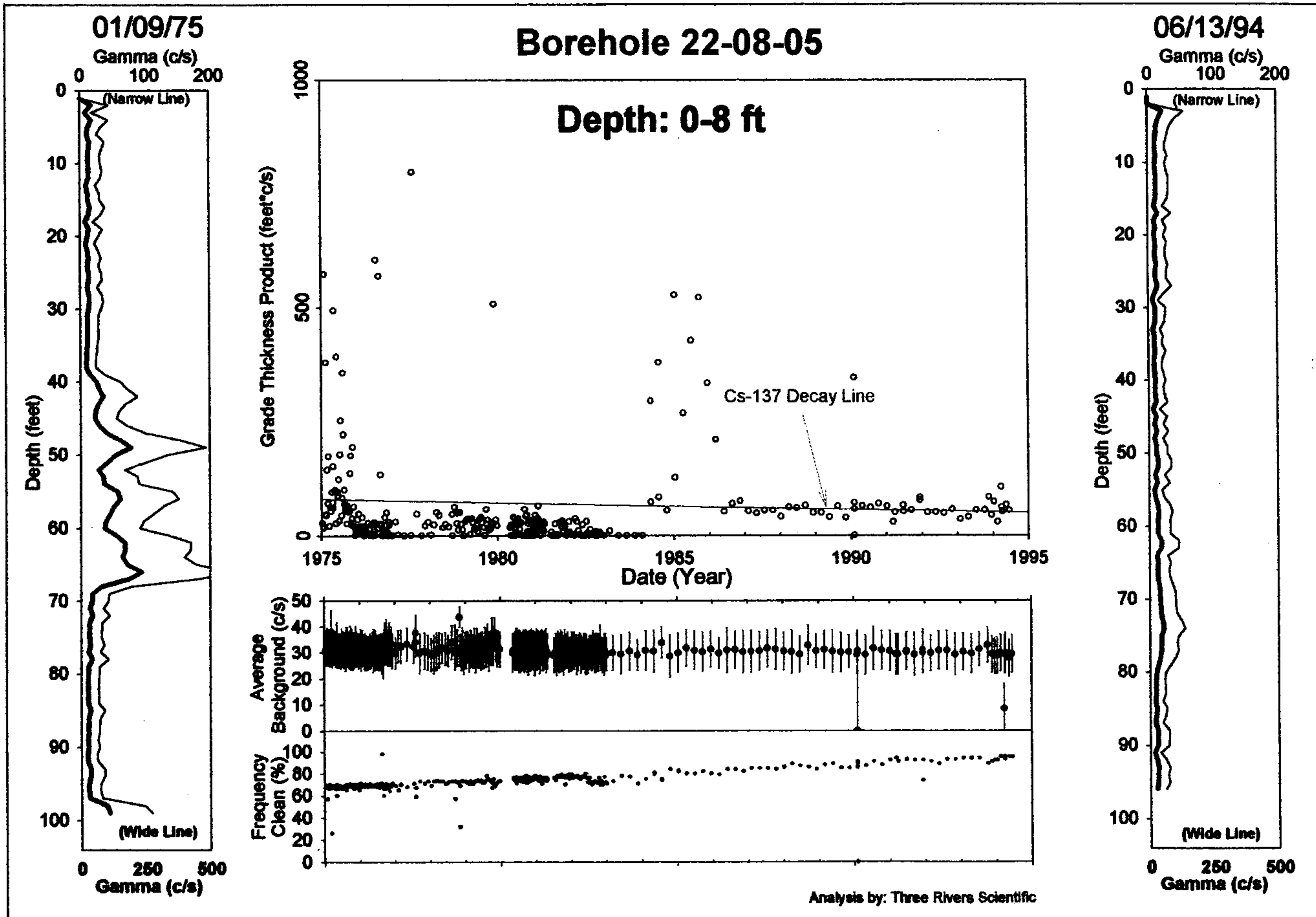
Borehole 22-08-05

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (4 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	6/13/1994
Number Surveys :	314

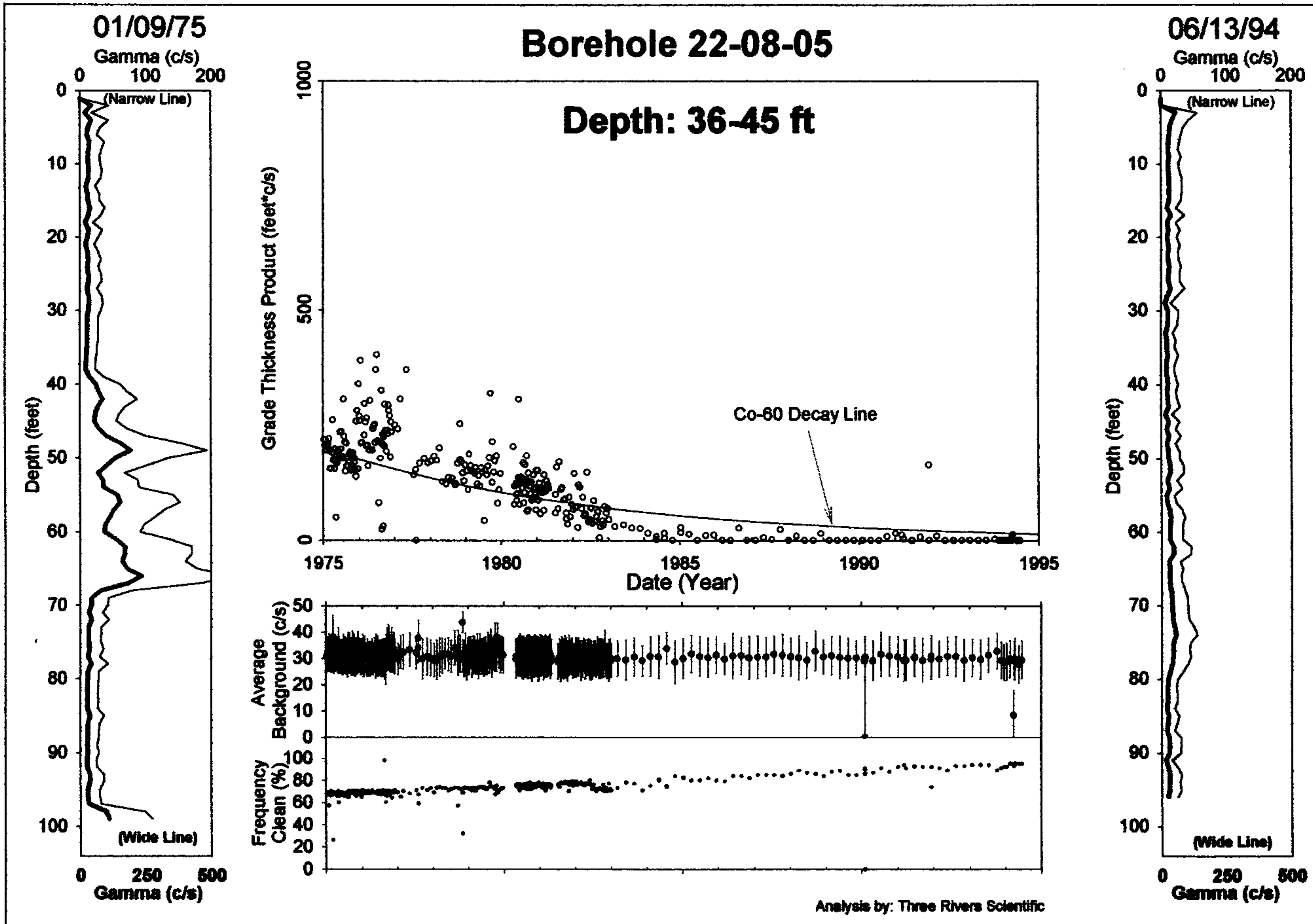
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	10 to 35 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-8 feet is TF Activity 36-45, 45-53, 53-63 feet is Stable 63-74, 74-84 feet was UNSTABLE
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



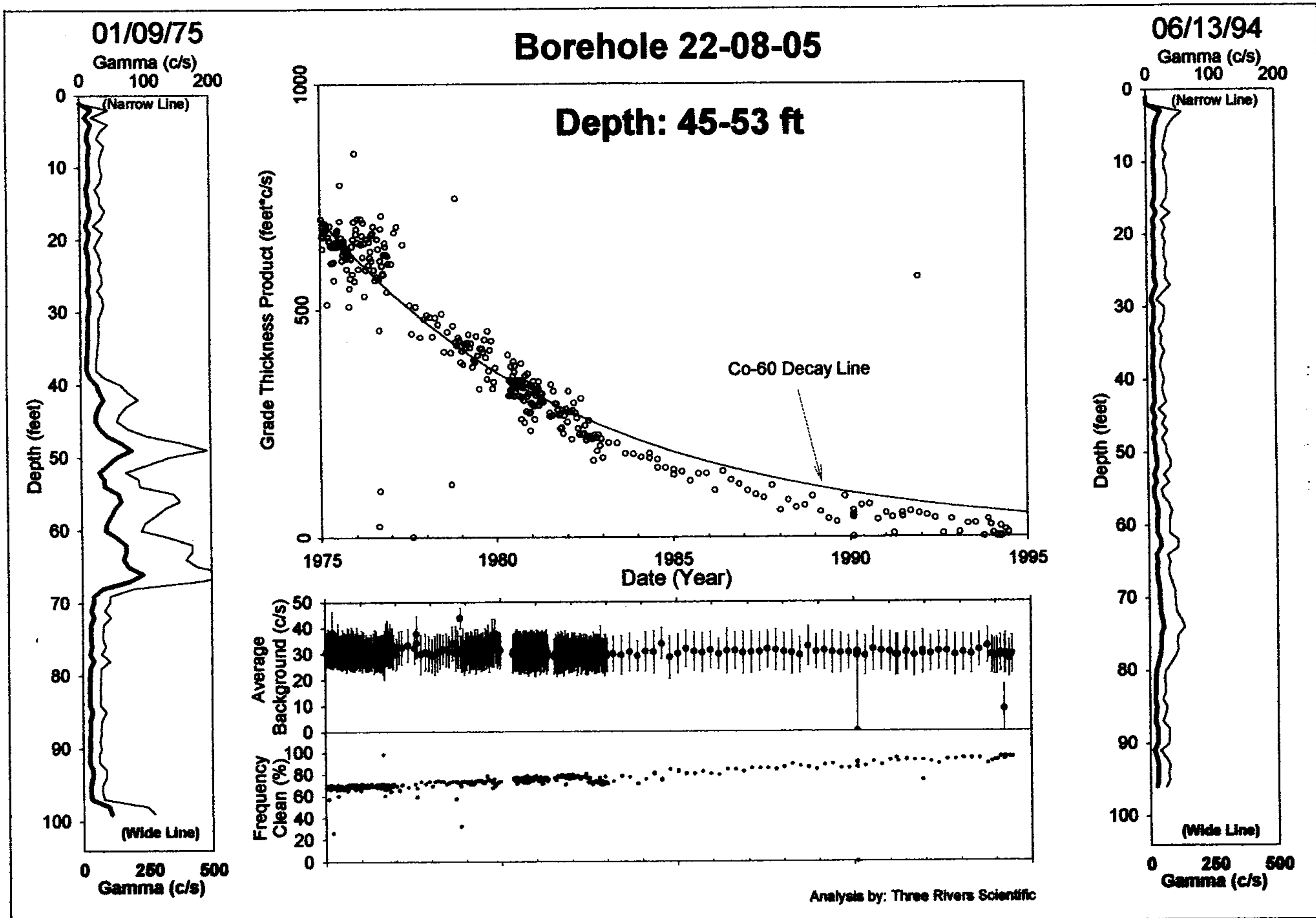
00 372

HNF-3532 -REV0



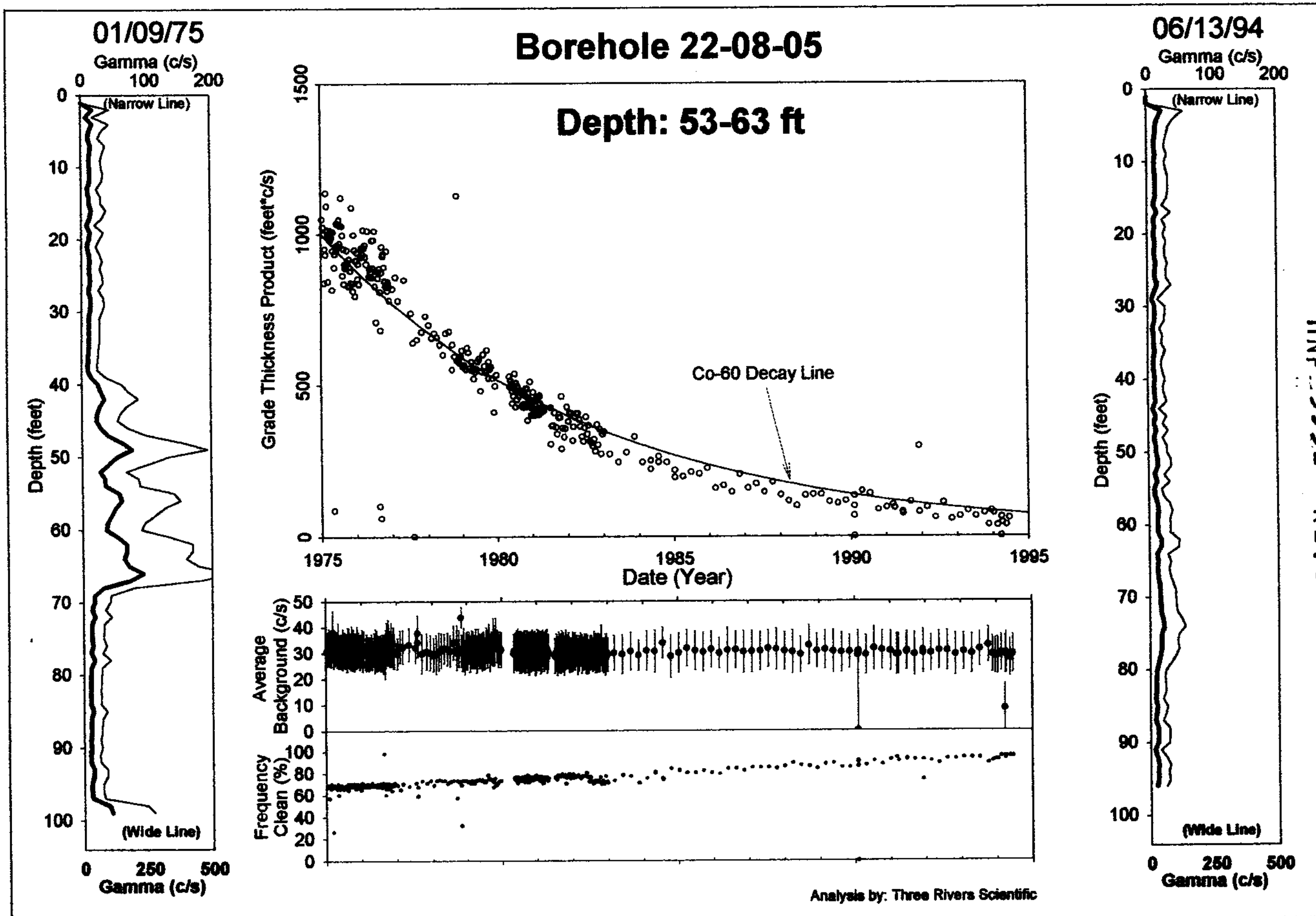
00 373

HNF-3532 -REV0

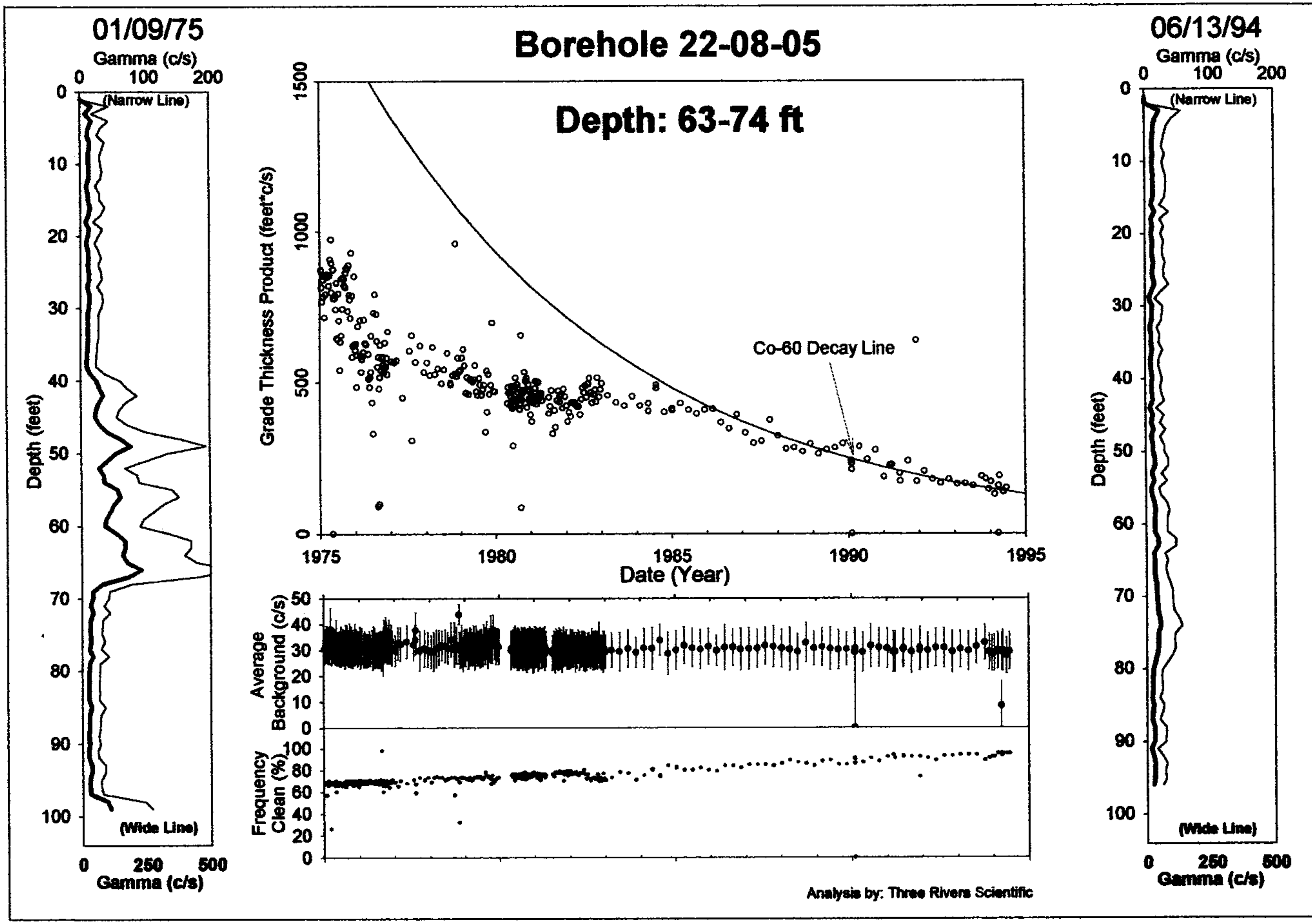


00 374

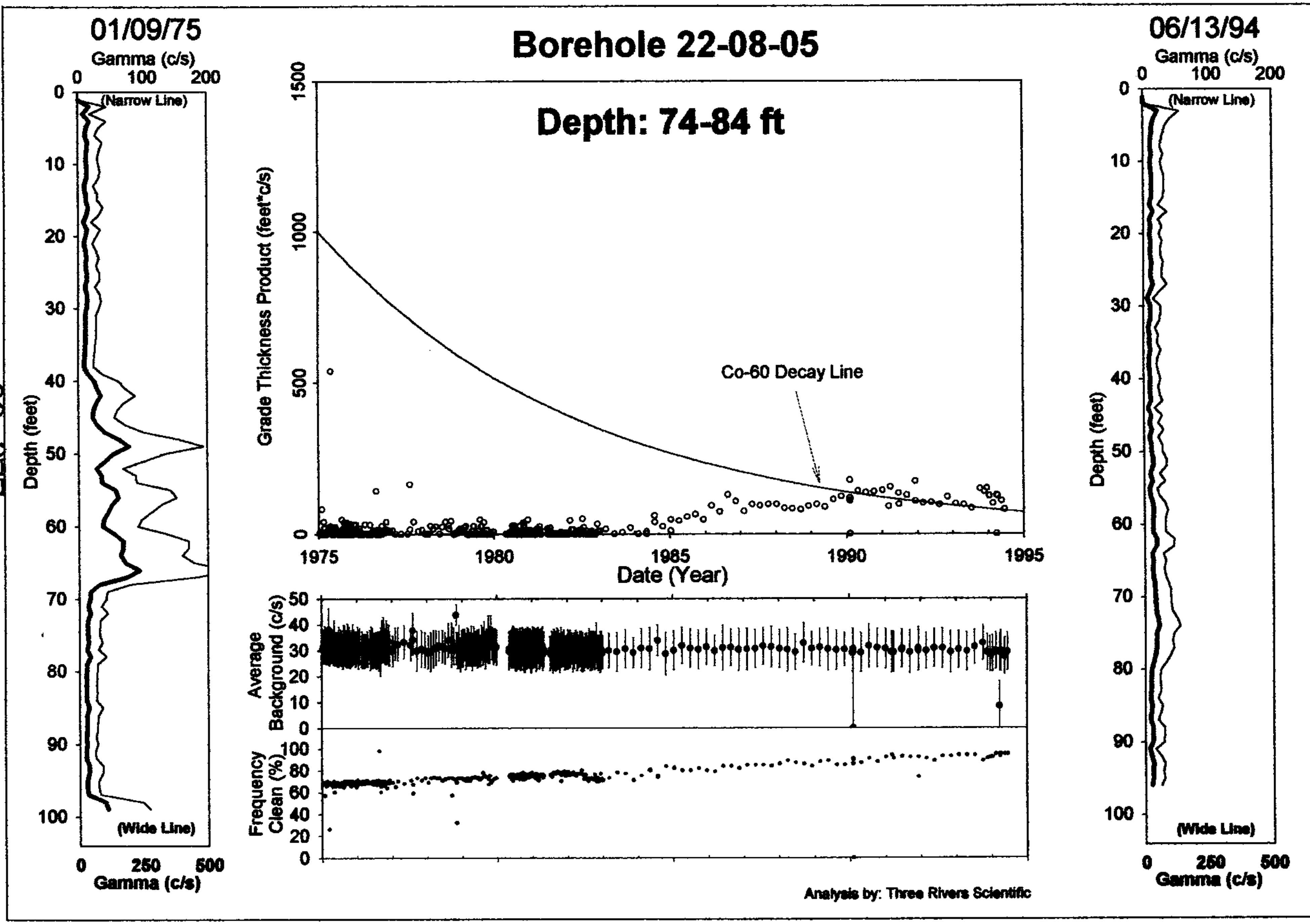
HNF-3532 - REV 0



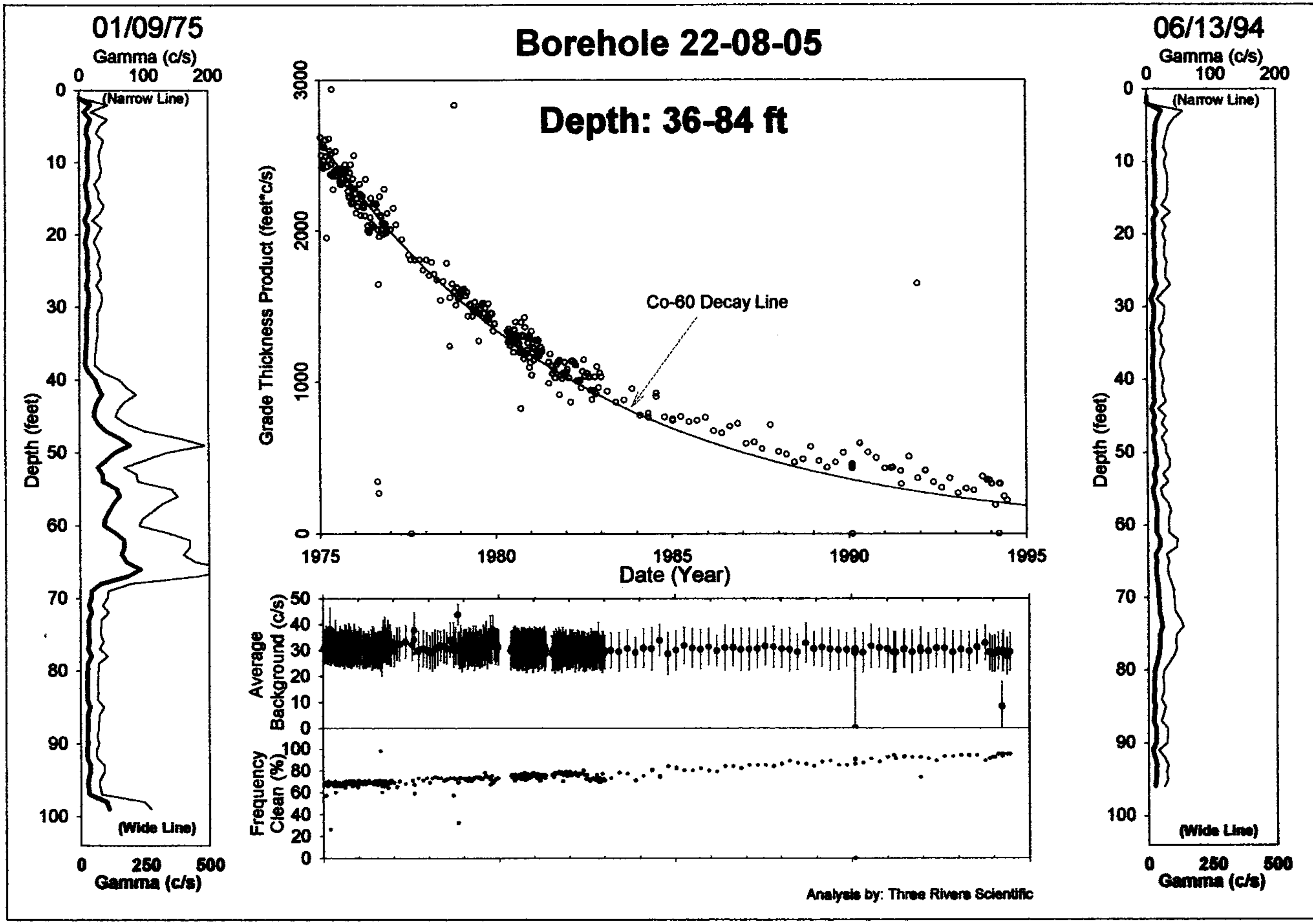
Borehole 22-08-05
Depth: 53-63 ft
01/09/75
06/13/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific



HNF-3532 -REV0

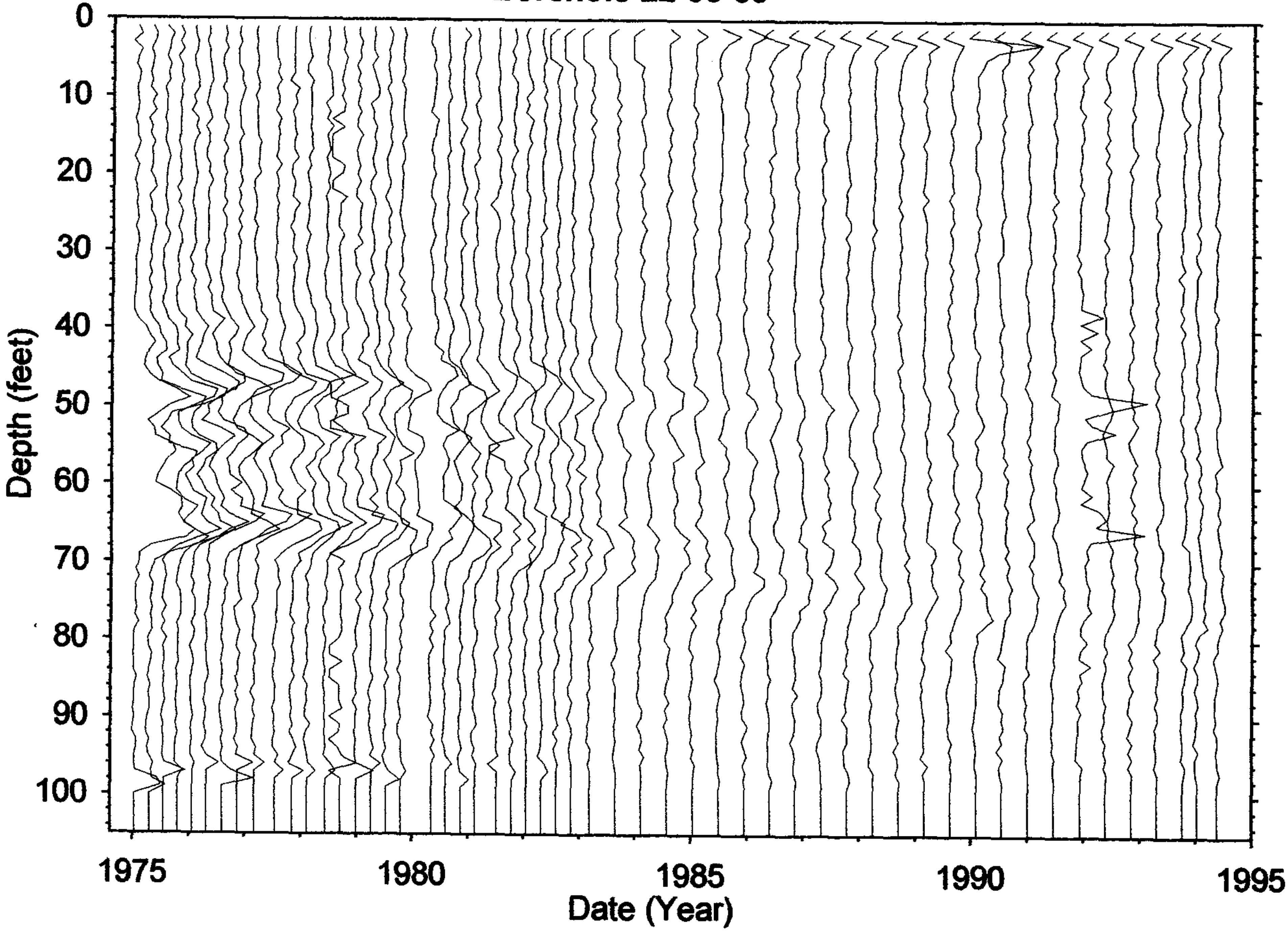


HNF-3532 -REV0



01/09/75
Gamma (c/s)
(Narrow Line)
Depth (feet)
(Wide Line)
Gamma (c/s)
Borehole 22-08-05
Depth: 36-84 ft
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
06/13/94
Gamma (c/s)
(Narrow Line)
Depth (feet)
(Wide Line)
Gamma (c/s)

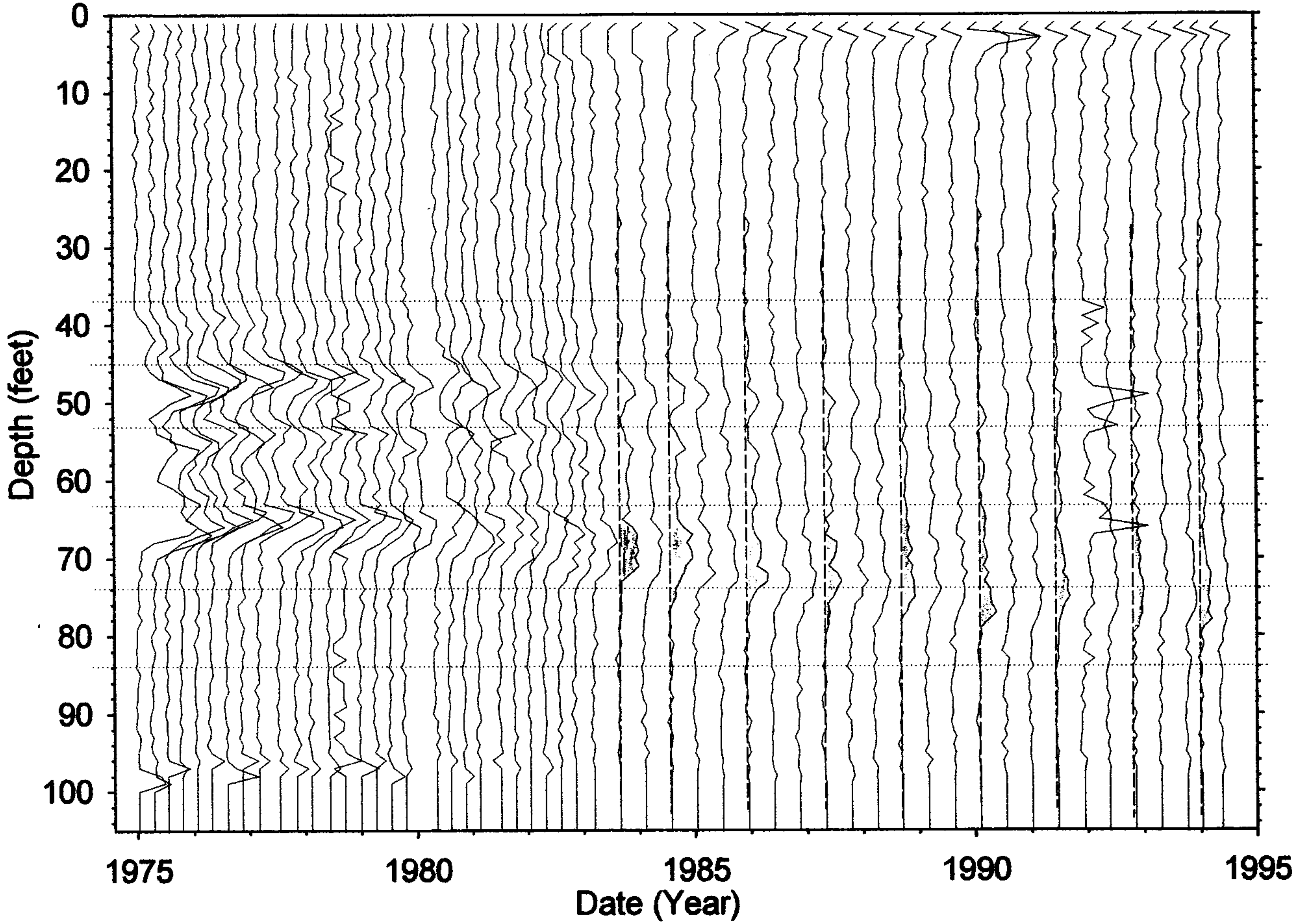
Borehole 22-08-05



HNF-3532 -REV0

00 379

Borehole 22-08-05



HNF-3532 -REV0

Borehole 22-08-06

page 1 of 2

Contamination (Cs-137) from 0 to 8 feet is Tank Farm Activity
Contamination (Cs-137) from 8 to 18 feet is Tank Farm Activity
Contamination (Cs-137) from 18-29 feet is Stable
Contamination (Cs-137 & Co-60) from 46-54 feet is Stable
Contamination (Co-60) from 54-63 feet is Stable
Contamination (Co-60) from 63-73 feet is Stable
Contamination (Co-60) from 73-83 feet is UNSTABLE early

Grade Thickness Product from 0 to 8 feet is erratic from 1975 through 1986, and is categorized as Tank Farm activity. In the radioactive zone from 8 to 18 feet the Grade Thickness Product from 1976 to 1985 is lower than the other time interval. In both zones the Grade Thickness Product from 1986 through 1994 is decreasing within counting statistics at a rate consistent with Cs-137 (identified from HPGe detector).

Grade Thickness Product for radioactive zone (18-29 feet) is decreasing within the gross gamma sensitivity at a rate consistent with Cs-137 (identified from HPGe detector) from 1975 through 1994.

Grade Thickness Product for radioactive zone (46-54 feet) is decreasing within the gross gamma sensitivity to each isotope and relative intensity at a rate consistent with Cs-137 and Co-60 (both identified from HPGe detector) from 1975 to 1995. The gross gamma contribution ratio for Co-60 to Cs-137 was 0.4 in 1995.

Grade Thickness Product for two radioactive zones (54-63 and 63-73 feet) is decreasing within the gross gamma sensitivity at a rate consistent with Co-60 (identified from HPGe detector) from 1975 through 1994.

Grade Thickness Product for the radioactive zone (73-83 feet) is roughly constant and below the radionuclide decay line for 1975, then from 1976 to 1995 the radioactive contaminant) is decreasing within the gross gamma sensitivity at a rate consistent with Co-60 (HPGe detector identified). The stack plot shows on close review that the broad gamma ray peak becomes better defined after 1975.

Grade Thickness Product of the combined radioactive zone (46-83 feet) is decreasing within the gross gamma sensitivity to each isotope and relative intensity at a rate consistent with a least squares fit of Co-60 and Cs-137 (both identified from HPGe detector) from 1975 to 1995. The least squares fit results in a gross gamma contribution ratio for Co-60 to Cs-137 of 1.1 on June 1994.

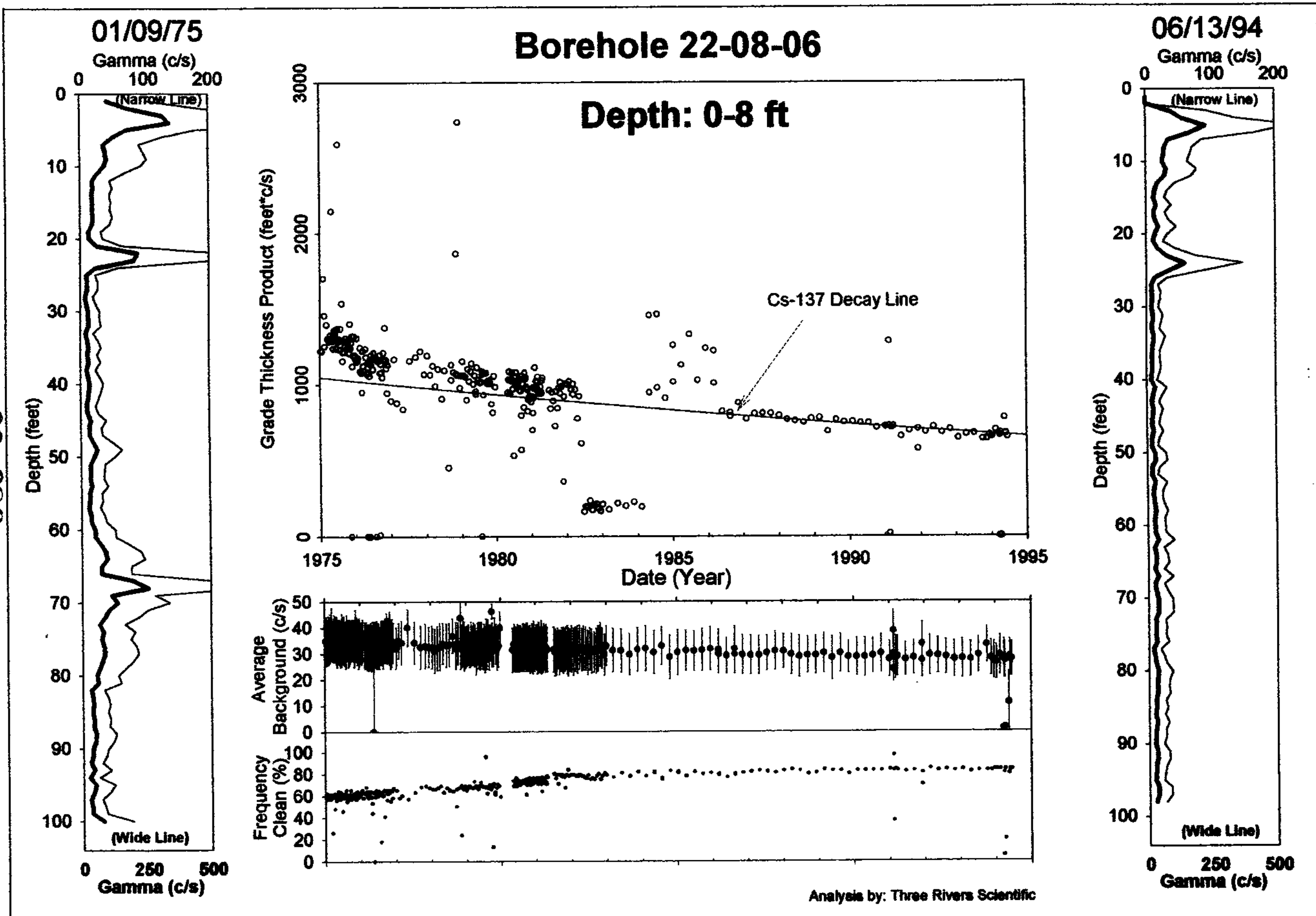
Borehole 22-08-06

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (2 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	6/13/1994
Number Surveys :	314

Analysis Notes

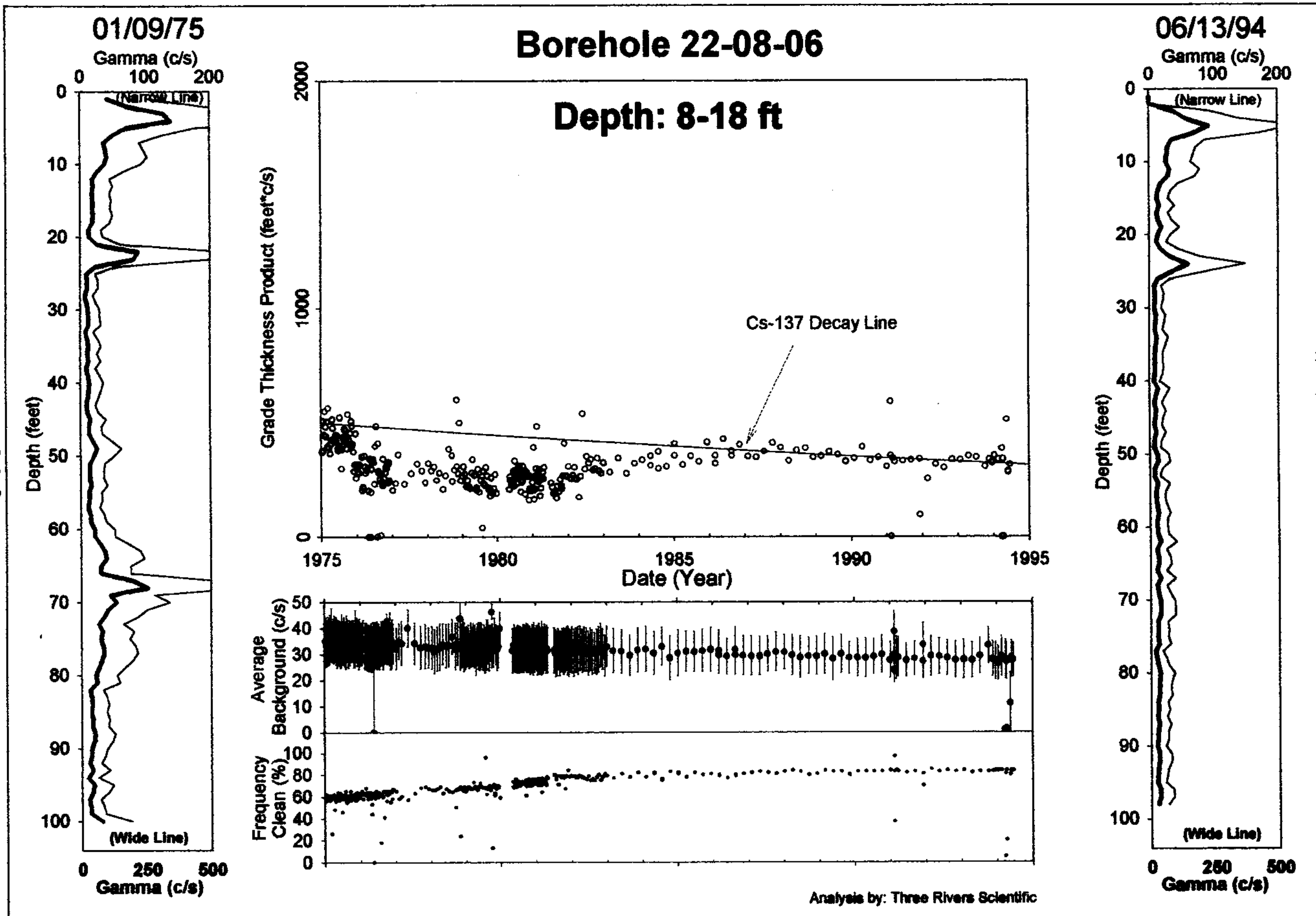
Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	30 to 46 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-8, 8-18 feet is TF Activity 18-29, 46-54, 54-63, 63-73 feet is Stable 73-83 feet was UNSTABLE early
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



00 383

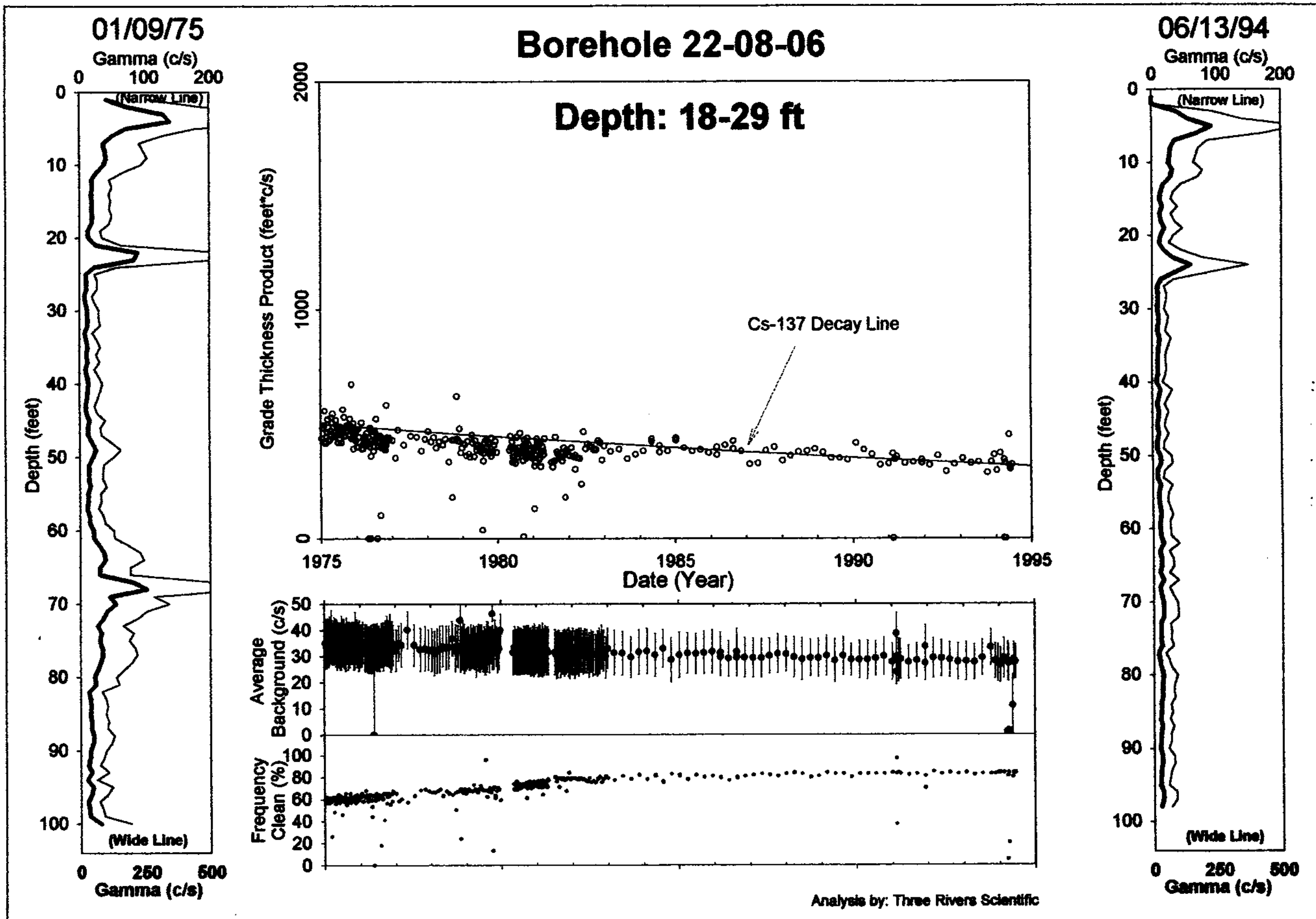
HNE-3532 -REV0

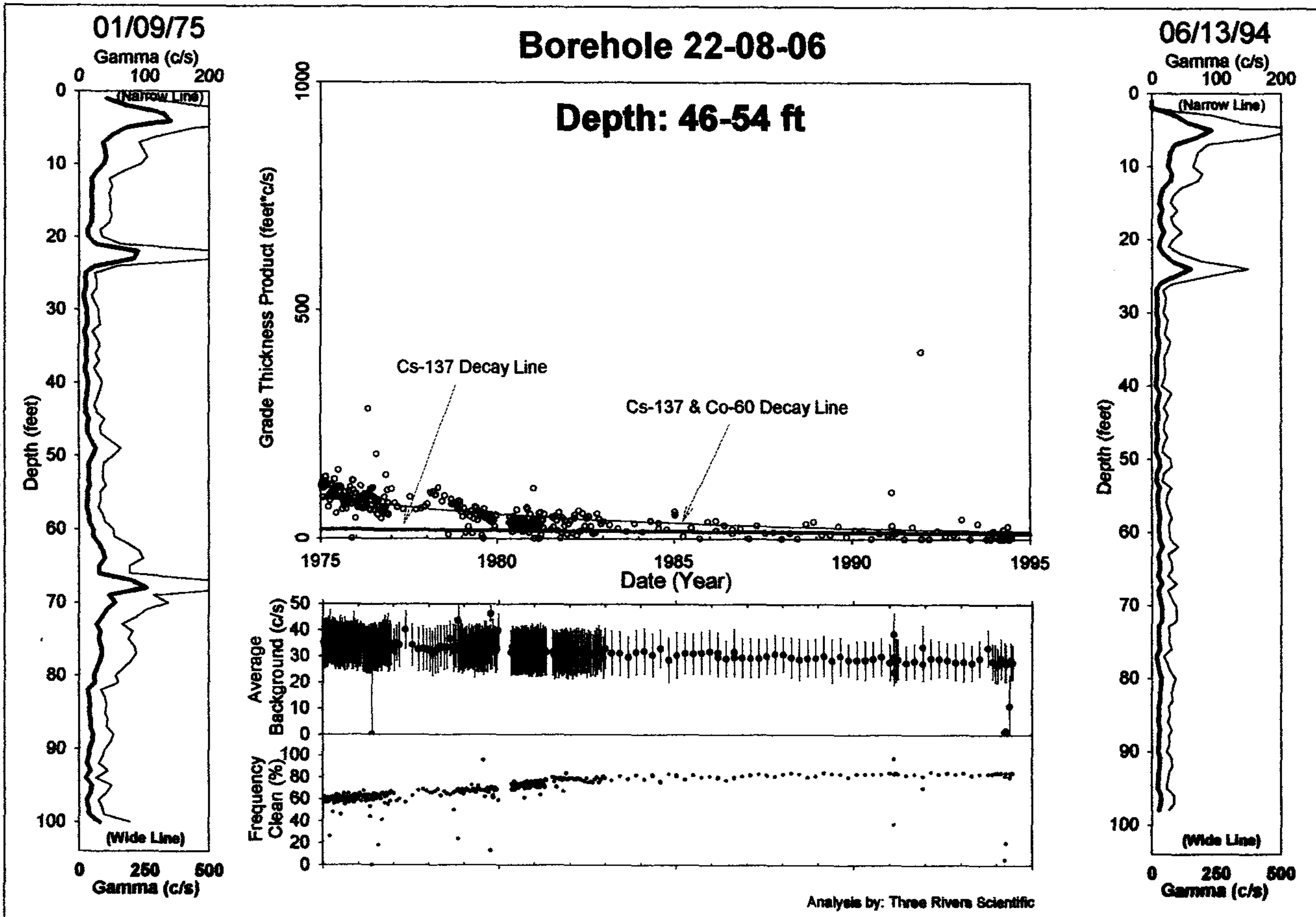
Borehole 22-08-06

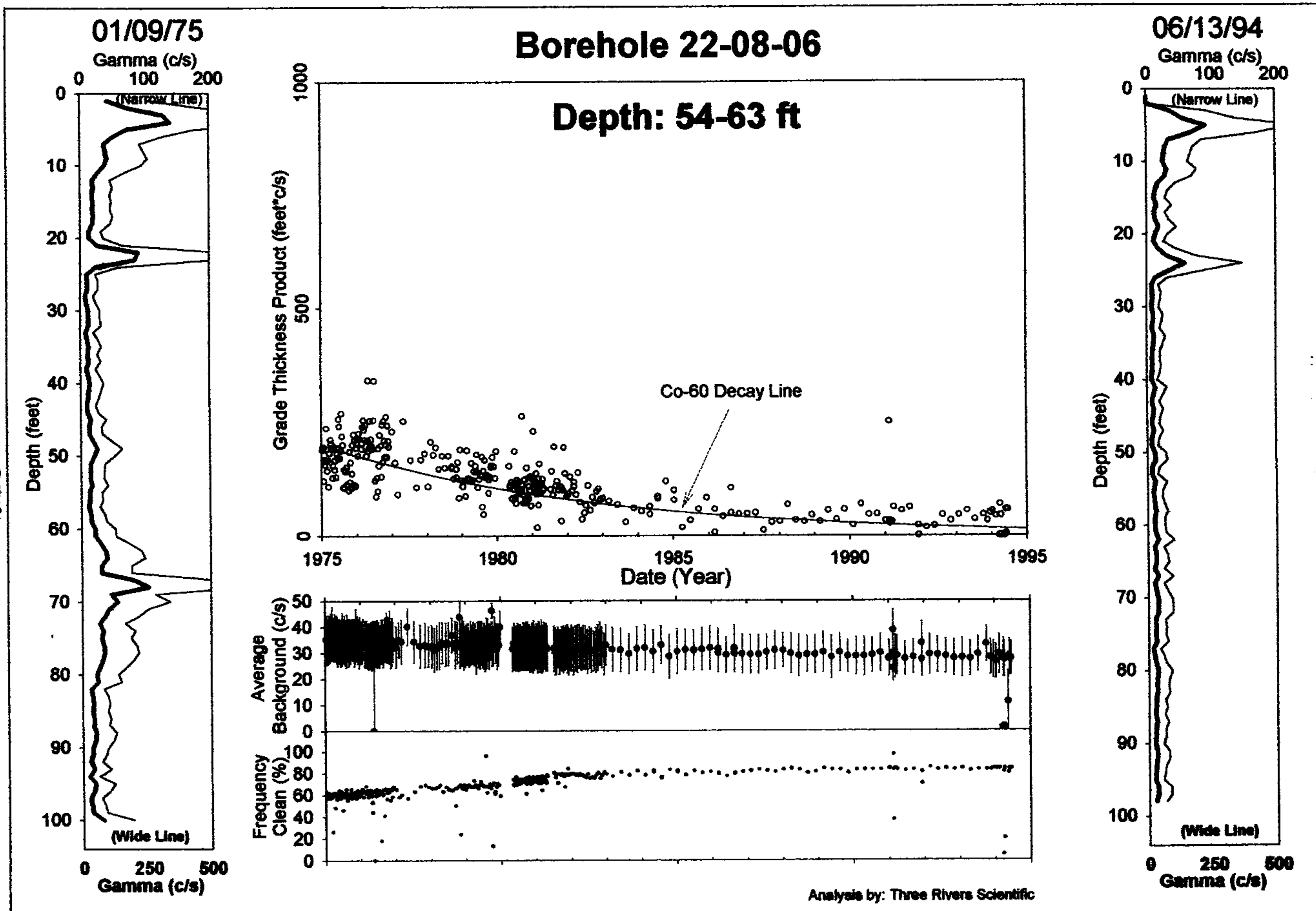


00 384

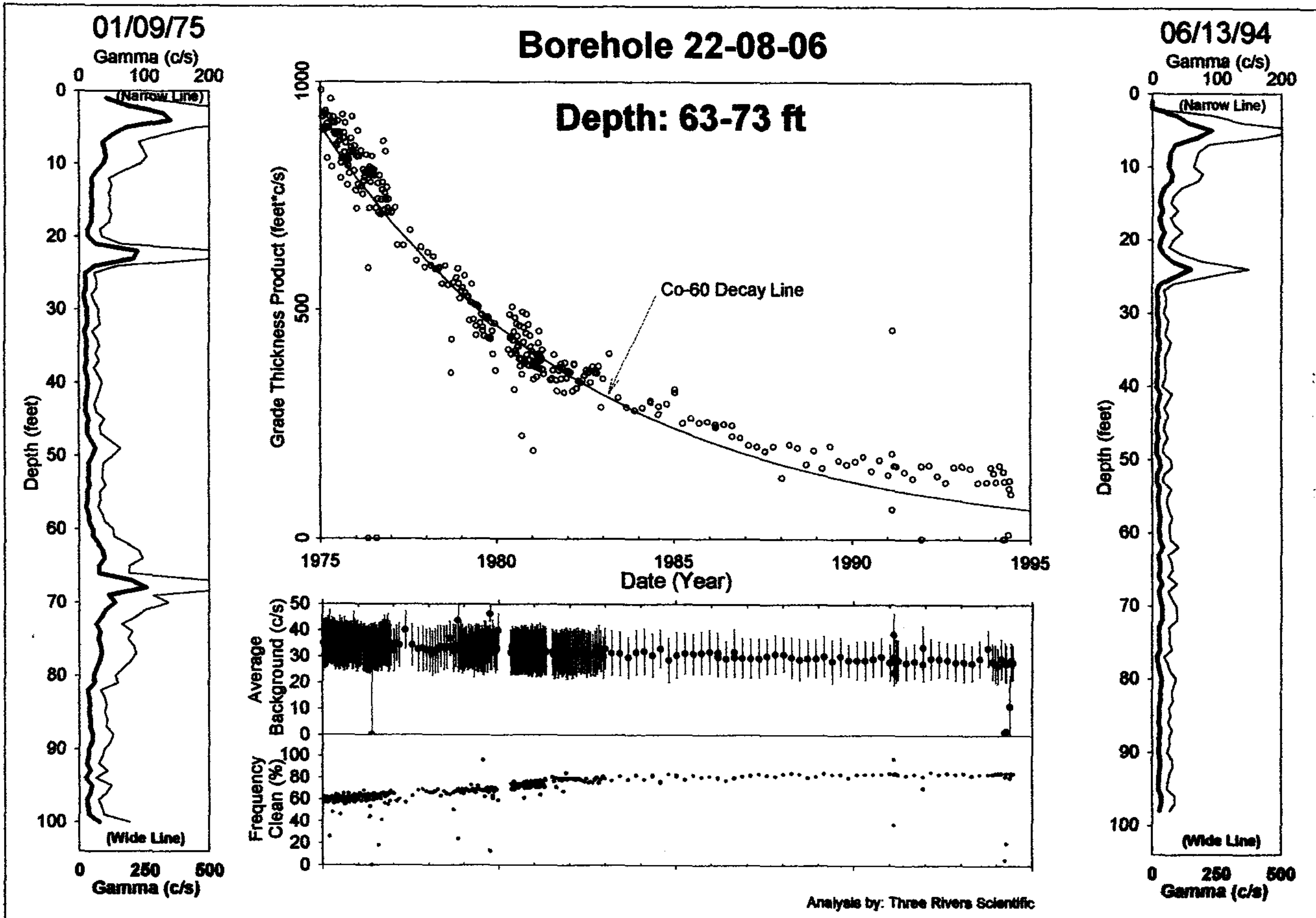
Borehole 22-08-06

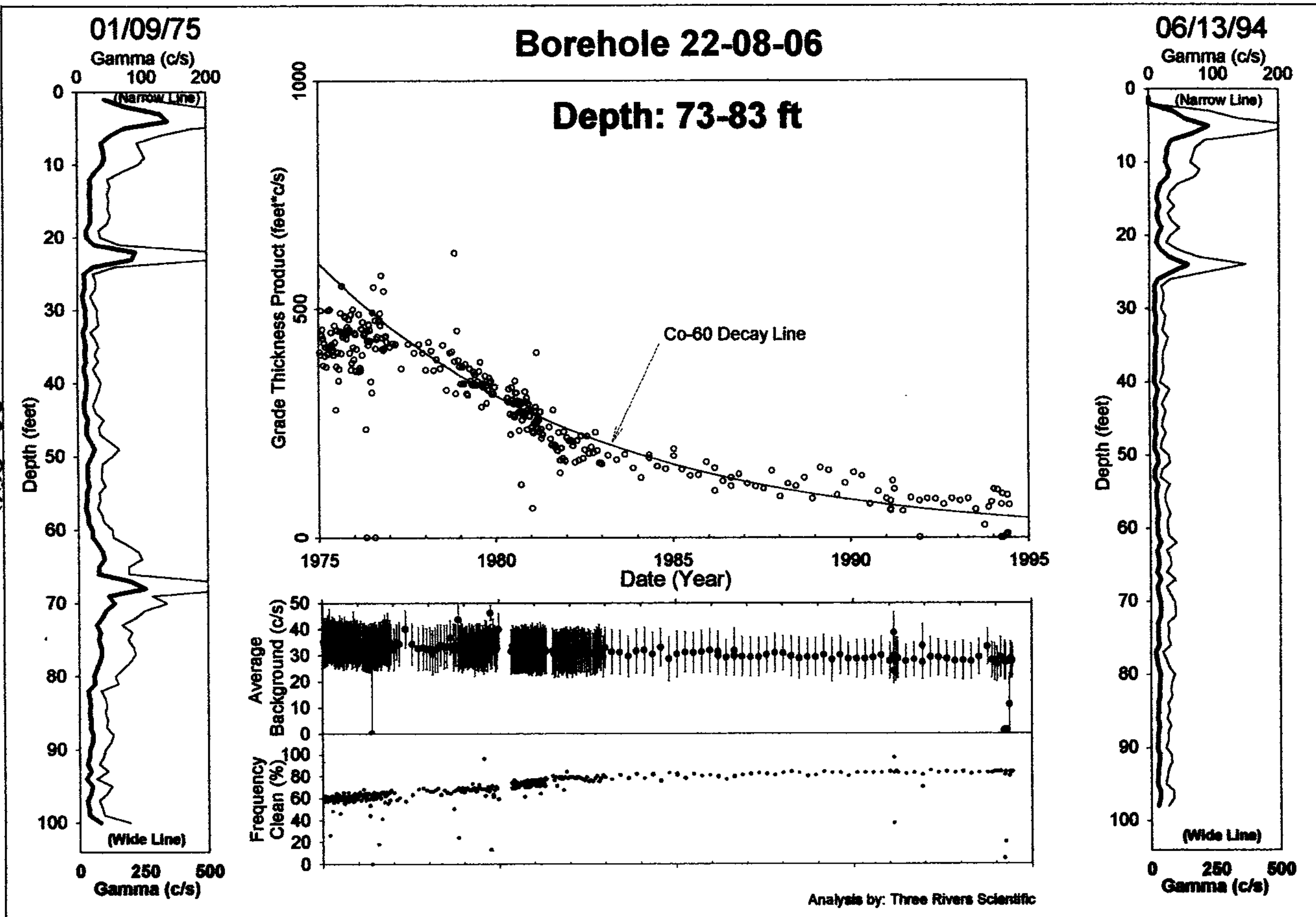



Borehole 22-08-06
Depth: 46-54 ft
01/09/75
06/13/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Cs-137 & Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific


01/09/75
Gamma (c/s)
(Narrow Line)
Depth (feet)
(Wide Line)
Gamma (c/s)
Borehole 22-08-06
Depth: 54-63 ft
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
06/13/94
Gamma (c/s)
(Narrow Line)
Depth (feet)
(Wide Line)
Gamma (c/s)

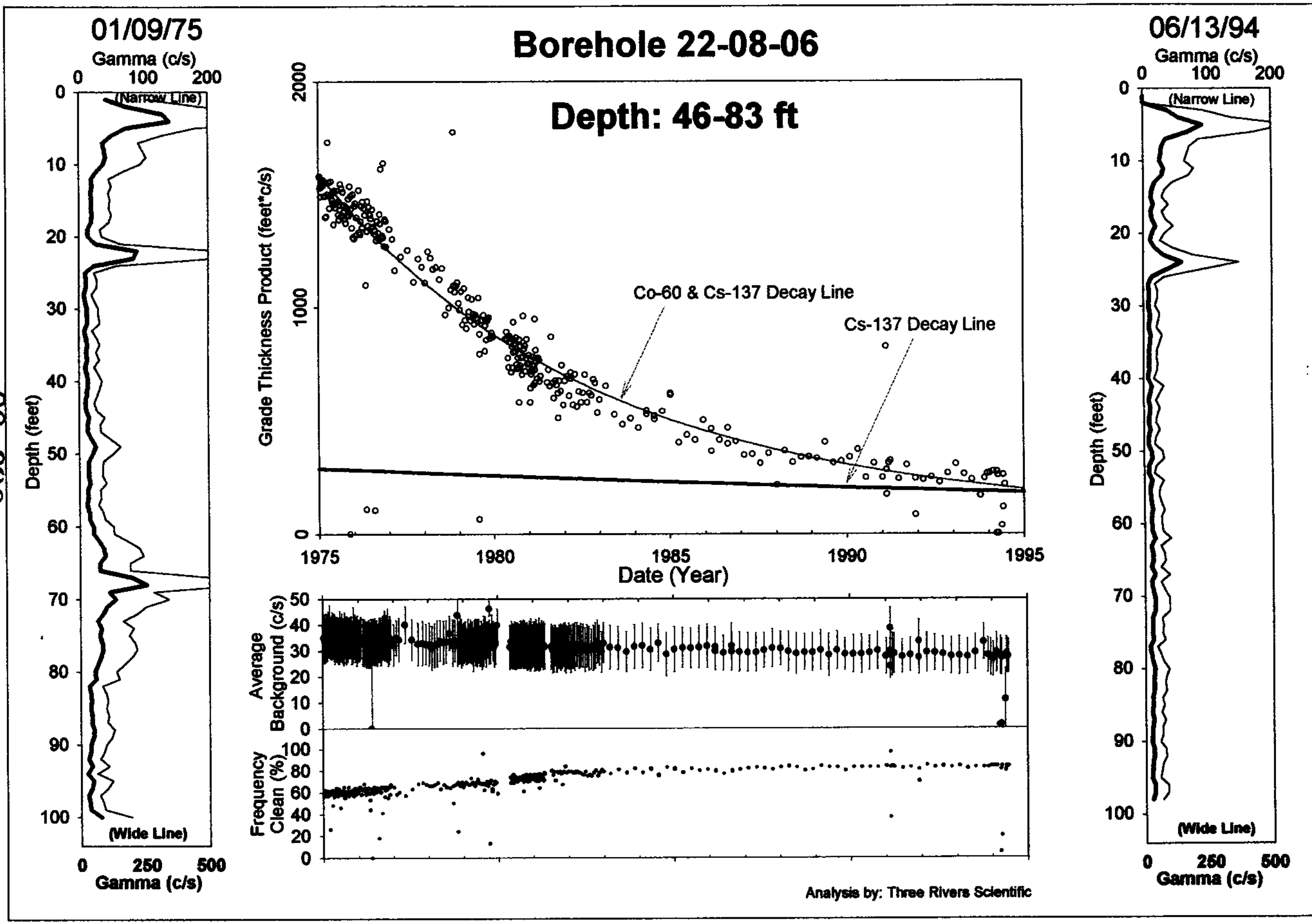
00 387


01/09/75
Gamma (c/s)
(Narrow Line)
Depth (feet)
(Wide Line)
Gamma (c/s)
Borehole 22-08-06
Depth: 63-73 ft
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
06/13/94
Gamma (c/s)
(Narrow Line)
Depth (feet)
(Wide Line)
Gamma (c/s)


Borehole 22-08-06
Depth: 73-83 ft
01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
06/13/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)

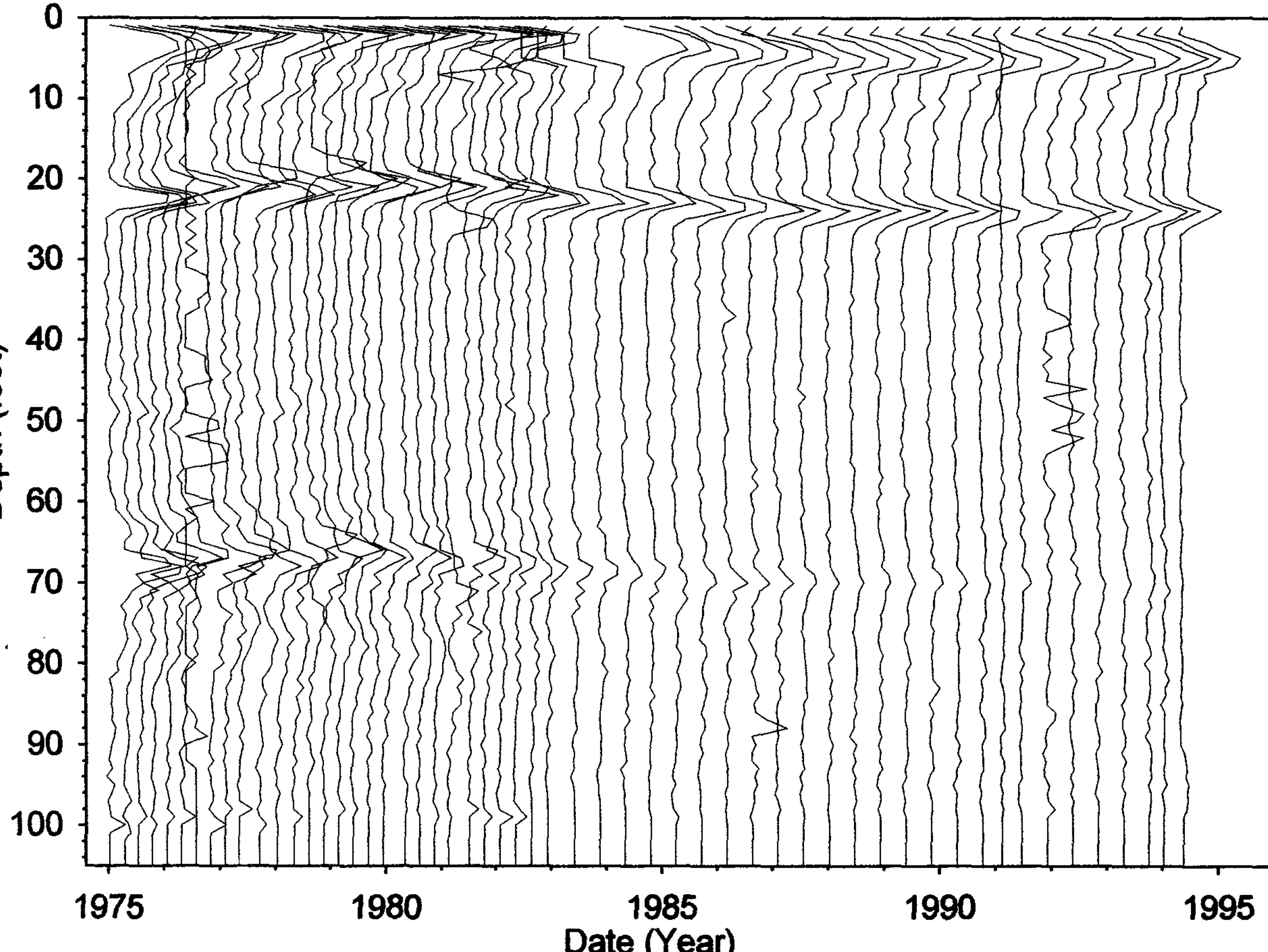
00 389

00 390



HNF-3532 -REV0

Borehole 22-08-06



HNF-3532 -REV0

1630391

Borehole 22-08-07

Contamination (Cs-137) from 0 to 8 feet is Tank Farm Activity

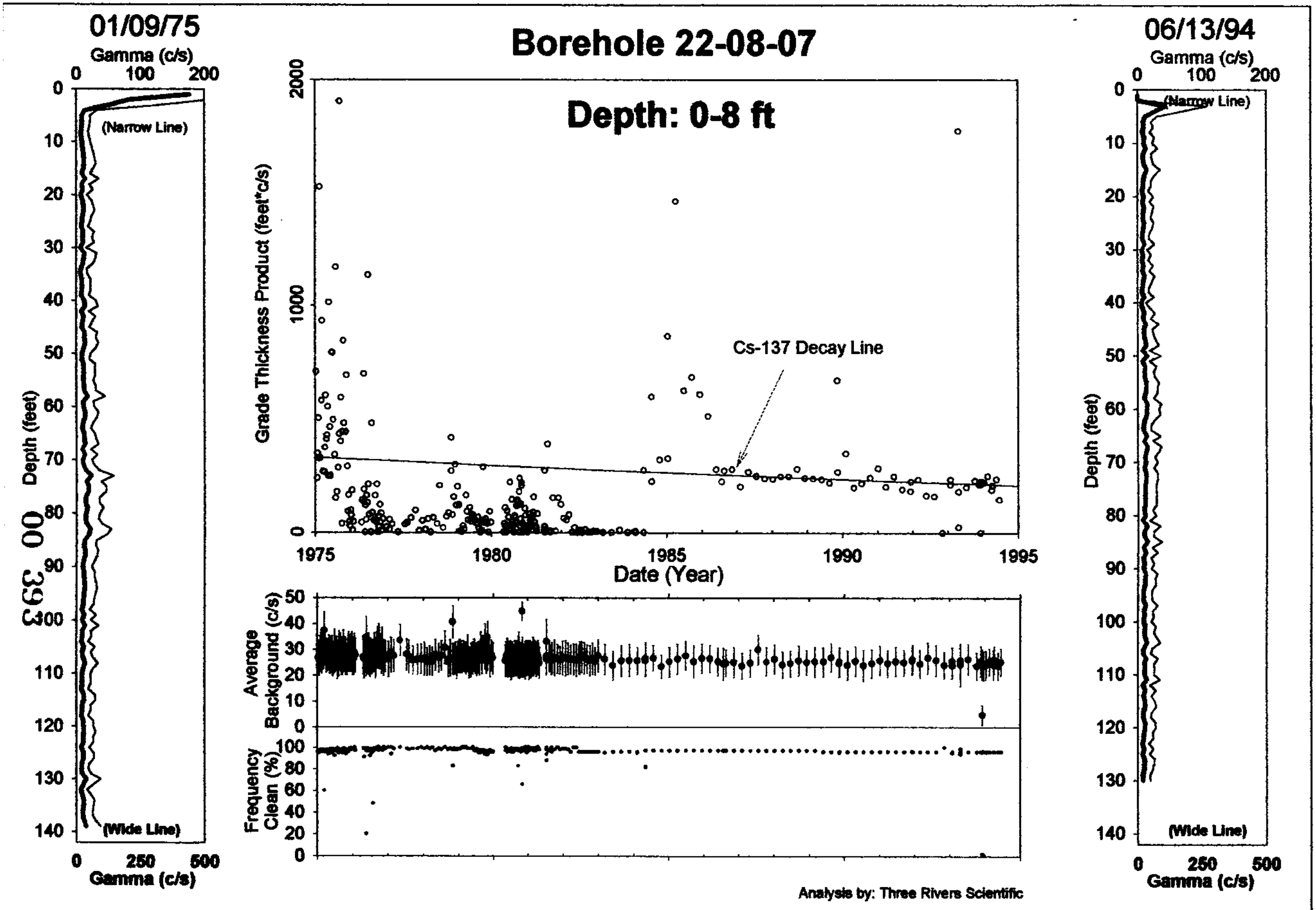
Grade Thickness Product from 0 to 8 feet is erratic from 1975 through 1986, and is categorized as Tank Farm activity. Grade Thickness Product from 1986 through 1994 is decreasing within counting statistics at a rate consistent with Cs-137 (identified from HPGe detector).

Gross Gamma Survey Information

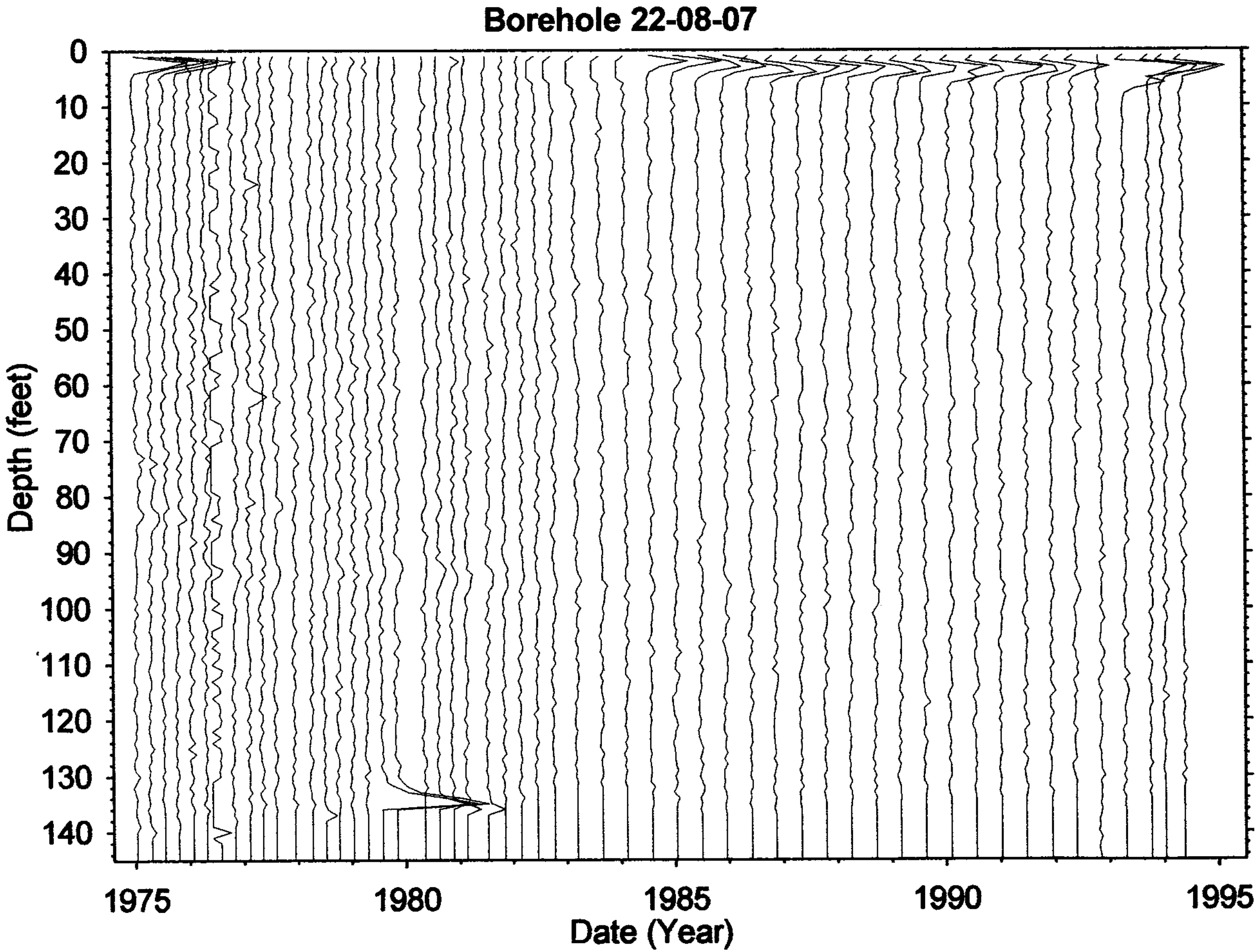
Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (5 surveys)
Borehole Depth :	135 ft
Survey Depth :	135 ft
First Survey Date :	1/09/1975
Last Survey Date :	6/13/1994
Number Surveys :	296

Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	20 to 40 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-8 feet is TF Activity
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



Borehole 22-08-07
Depth: 0-8 ft
01/09/75
Gamma (c/s)
0 100 200
Depth (feet)
(Narrow Line)
(Wide Line)
0 250 500
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
1975 1980 1985 1990 1995
Average Background (c/s)
Frequency Clean (%)
06/13/94
Gamma (c/s)
0 100 200
Depth (feet)
(Narrow Line)
(Wide Line)
0 250 500
Gamma (c/s)
Analysis by: Three Rivers Scientific



HNF-3532 -REV0

00 394

Borehole 22-08-09

Contamination (Cs-137) from 0 to 10 feet is Tank Farm Activity
Contamination (Cs-137 & Ru-106) from 72 to 84 feet was <u>UNSTABLE</u> early

Grade Thickness Product from 0 to 8 feet is erratic from 1975 through 1986, and is categorized as Tank Farm activity. Grade Thickness Product from 1986 through 1994 is decreasing within counting statistics at a rate consistent with Cs-137 (identified from HPGe detector).

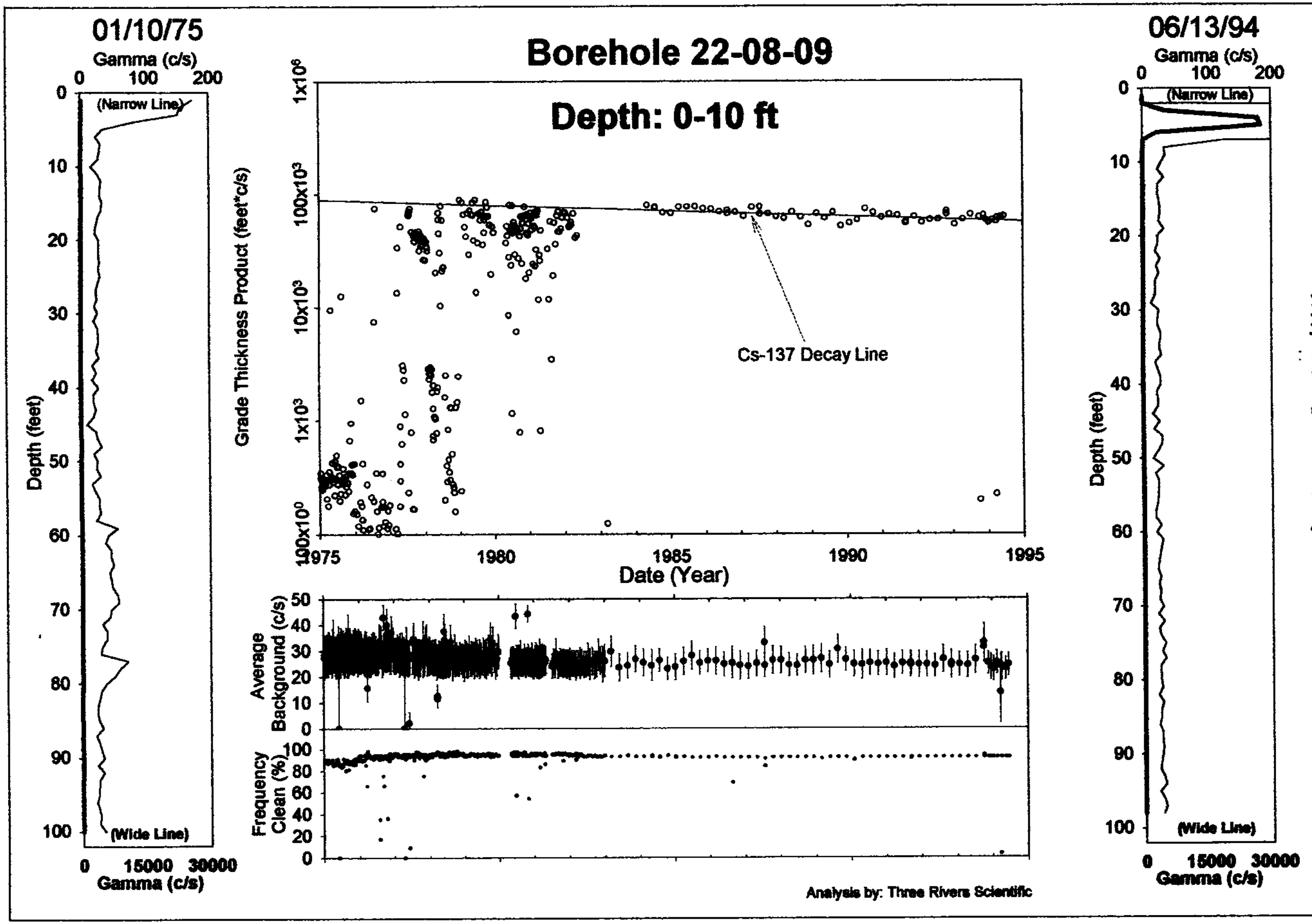
Grade Thickness Product for the radioactive zone (72-84 feet) for 1975 was <u>INCREASING.</u> Then from 1976 to 1995 Grade Thickness Product was decreasing at a rate consistent with the decay of Ru-106 (hypothesis) and Cs-137 (identified from HPGe detector). The gross gamma contribution ratio for Ru-106 to Cs-137 was 3.5 on January 1, 1976.

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (2 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/10/1975
Last Survey Date :	6/13/1994
Number Surveys :	403

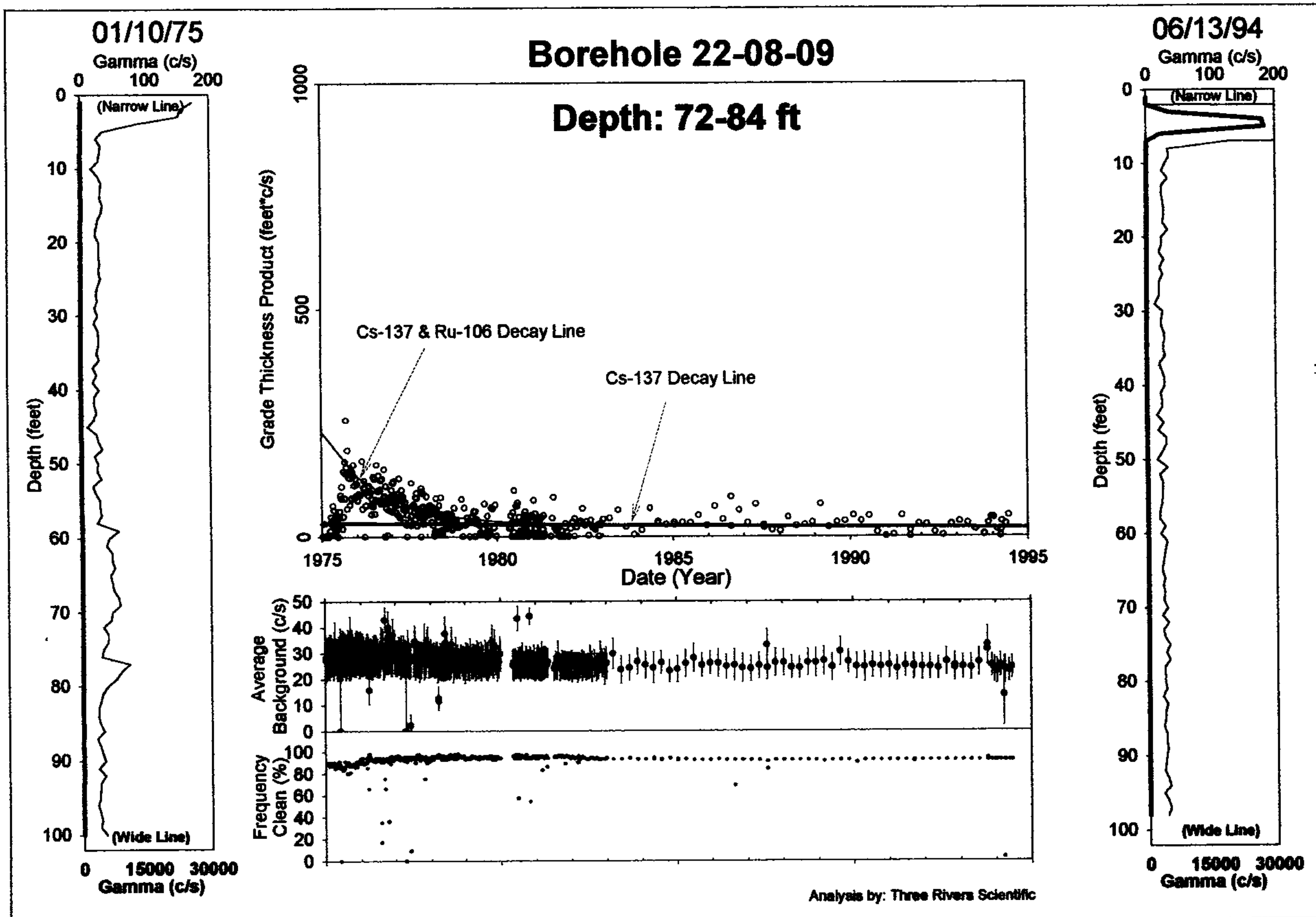
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	50 to 70 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 feet is TF Activity 72-84 feet was UNSTABLE early
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



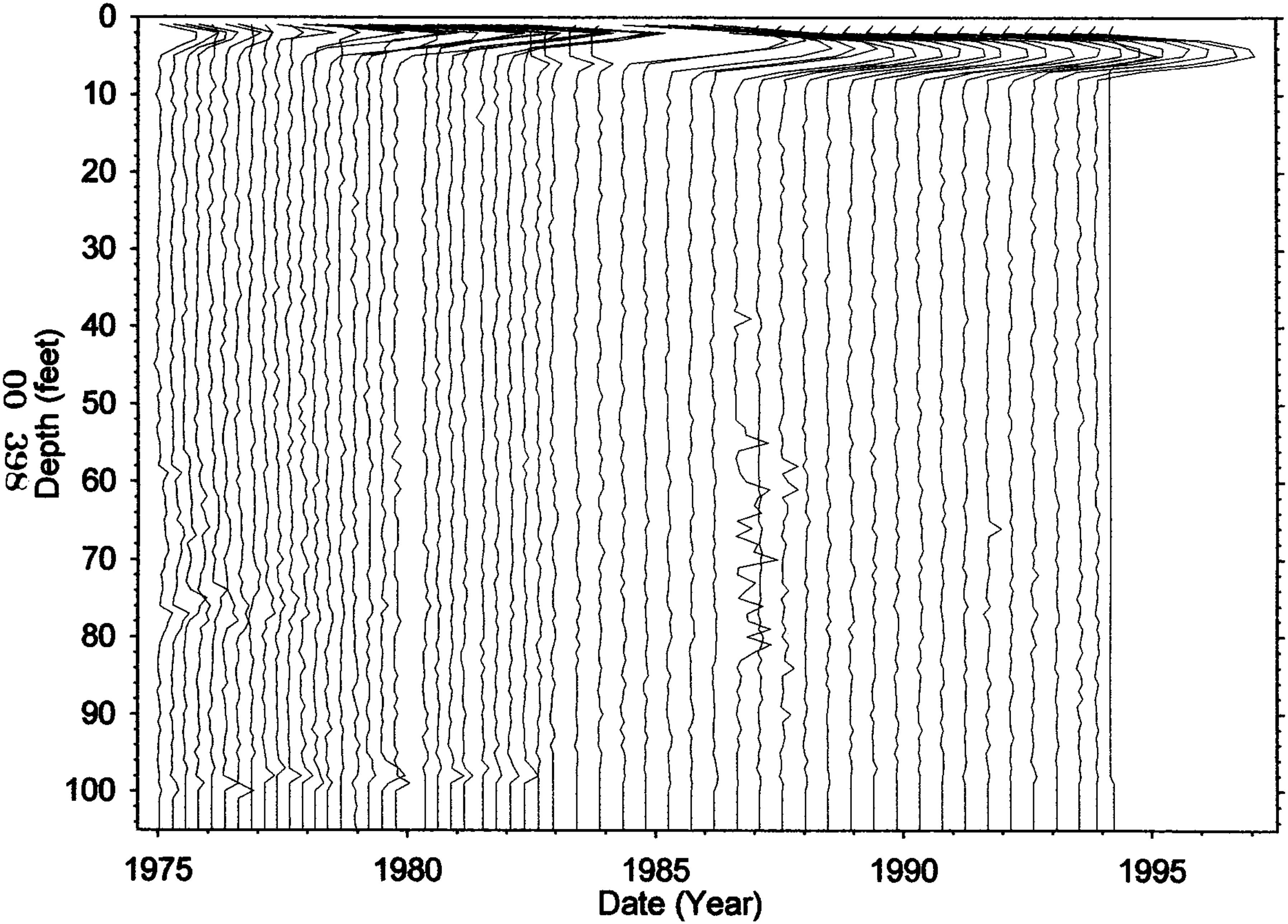
HNF-3532-REV0

00 396



Borehole 22-08-09
Depth: 72-84 ft
01/10/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Cs-137 & Ru-106 Decay Line
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
06/13/94
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)

Borehole 22-08-09



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Borehole 22-08-12

page 1 of 2

Contamination (Cs-137) from 0 to 8 feet is Tank Farm Activity
Contamination (Cs-137) from 25-40 feet is **UNSTABLE**
Contamination (Co-60 & Sb-125) 40-51feet **UNSTABLE** early
Contamination (Co-60) from 51-60 feet is **UNSTABLE**
Contamination (Co-60) from 60-70 feet is **UNSTABLE** early
Contamination (Co-60) from 70-82 feet is **UNSTABLE** early

Grade Thickness Product from 0 to 8 feet is erratic for the 20 year surveillance period, and is categorized as Tank Farm activity. Grade Thickness Product is plotted on a logarithmic scale to show the variability of the computed results. A decay line for Cs-137 (identified from HPGe detector) is shown but does not fit a significant number of surveys.

Grade Thickness Product for radioactive zone (25-40 feet) shows a consistent INCREASE from 1978 to 1980 then a decrease from 1980 to 1983. The decay rate of the isotope that migrated through the zone (25-40 feet) could not be identified. A decay lilne for Cs-137 (low level identified from HPGe detector) is shown but does not fit the data.

Grade Thickness Product for the radioactive zone (40-51 feet) is decreasing in 1975 at a rate that is greater than the decay of Sb-125 (hypothesis) and Co-60 (identified from HPGe detector), then after 1976 exhibits a reasonable fit to the decay line. In 1982 a decrease in the Grade Thickness Product is observed. The gross gamma contribution ratio for Sb-125 to Co-60 was 0.4 in 1995.

Grade Thickness Product for the radioactive zone (51-60 feet) shows a decrease from 1975 to 1980 that does not fit the remainder of the monitoring logs. From 1980 to 1982 the Grade Thickness Product is erratic and increases, then begins to decrease at a rate consistent with the decay of Co-60 (identified from HPGe detector) from 1982 to 1995. Downward movement of the contamination may be occurring.

Grade Thickness Product for the radioactive zone (60-70 feet) is greater than the decay rate of Co-60 (identified from HPGe detector) from 1975 to 1983. Then from 1983 to 1995 the Grade Thickness Product decay rate is consistent with Co-60. The stack plot shows movement down of contamination through this zone to the next lower zone.

Grade Thickness Product for the radioactive zone (70-82 feet) shows the contaminants to be INCREASING from 1975 to 1983. Then from 1983 to 1995 the Grade Thickness Product is decreasing at a rate that is consistent with Co-60(identified from HPGe detector).

Borehole 22-08-12

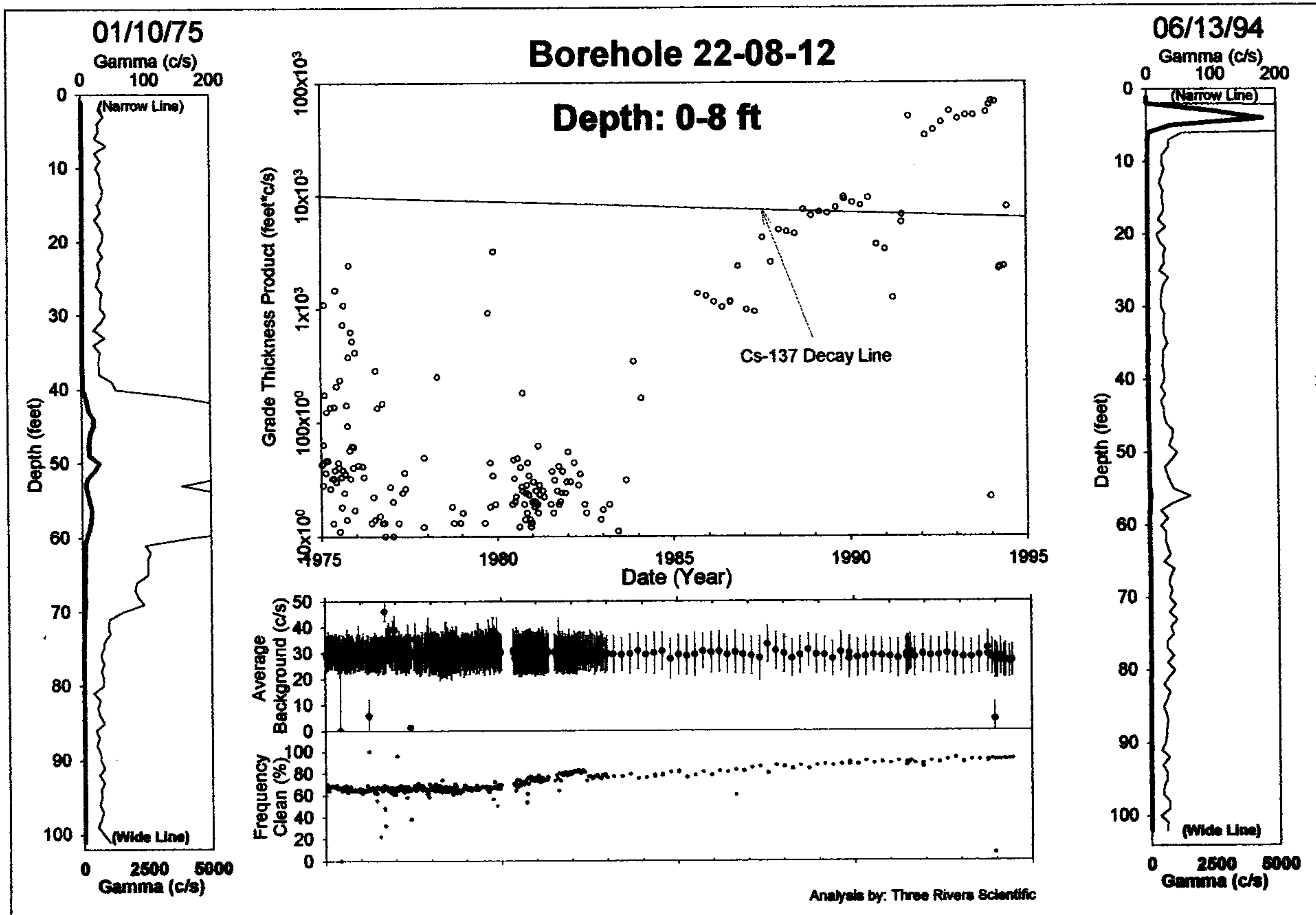
Grade Thickness Product for the combined radioactive zone (40-82 feet) is greater than the decay rate of Sb-125 (hypothesis) and Co-60 (identified from HPGe detector) in 1975. Then from 1976 to 1995 the Grade Thickness Product rate of decrease is consistent with the decay of Sb-125 and Co-60. The gross gamma contribution ratio for Sb-125 to Co-60 of 0.04 on January 1996.

Gross Gamma Survey Information

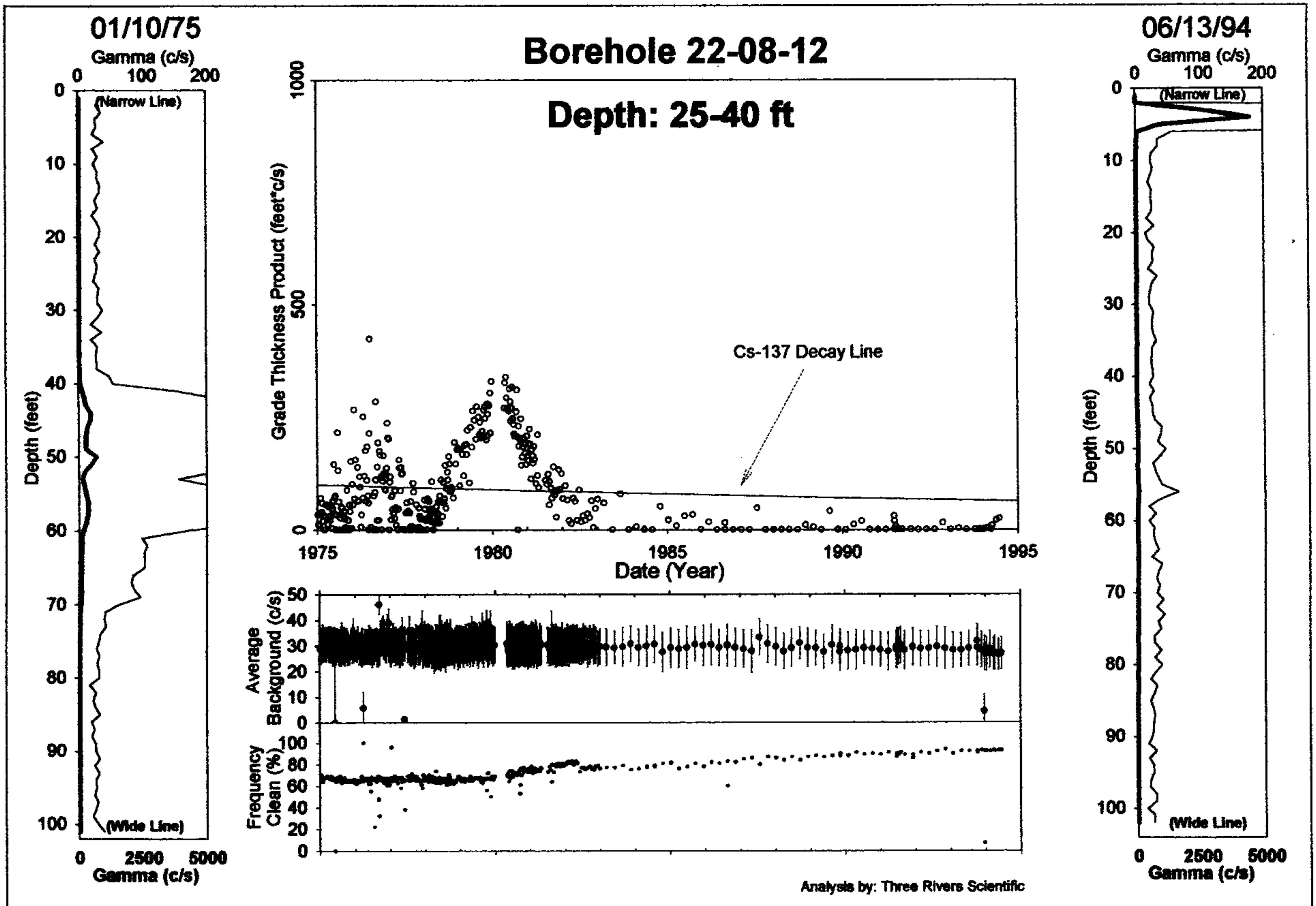
Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (3 surveys)
Borehole Depth :	105 ft
Survey Depth :	105 ft
First Survey Date :	1/10/1975
Last Survey Date :	6/13/1994
Number Surveys :	380

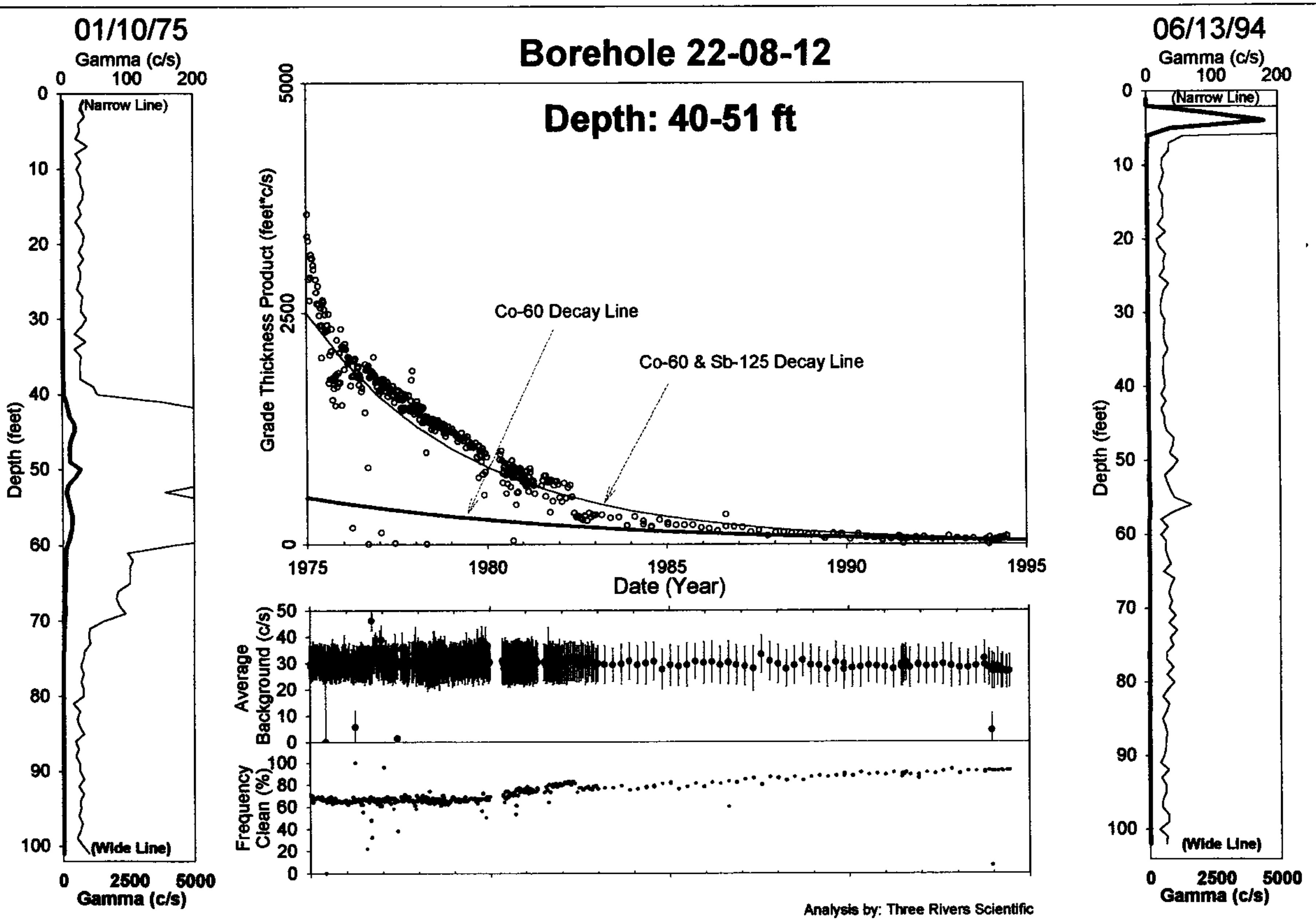
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	10 to 24 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-8 feet is TF Activity 24-40, 40-51, 51-60, 60-70, and 70-82 feet was UNSTABLE
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



Borehole 22-08-12
Depth: 0-8 ft
01/10/75
Gamma (c/s)
0
100
200
(Narrow Line)
(Wide Line)
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
0
2500
5000
Gamma (c/s)
Grade Thickness Product (feet*c/s)
10x10⁰
100x10⁰
1x10³
10x10³
100x10³
Cs-137 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average Background (c/s)
0
10
20
30
40
50
Frequency Clean (%)
0
20
40
60
80
100
Analysis by: Three Rivers Scientific
06/13/94
Gamma (c/s)
0
100
200
(Narrow Line)
(Wide Line)
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
0
2500
5000
Gamma (c/s)


Borehole 22-08-12
Depth: 25-40 ft
01/10/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
06/13/94
Analysis by: Three Rivers Scientific



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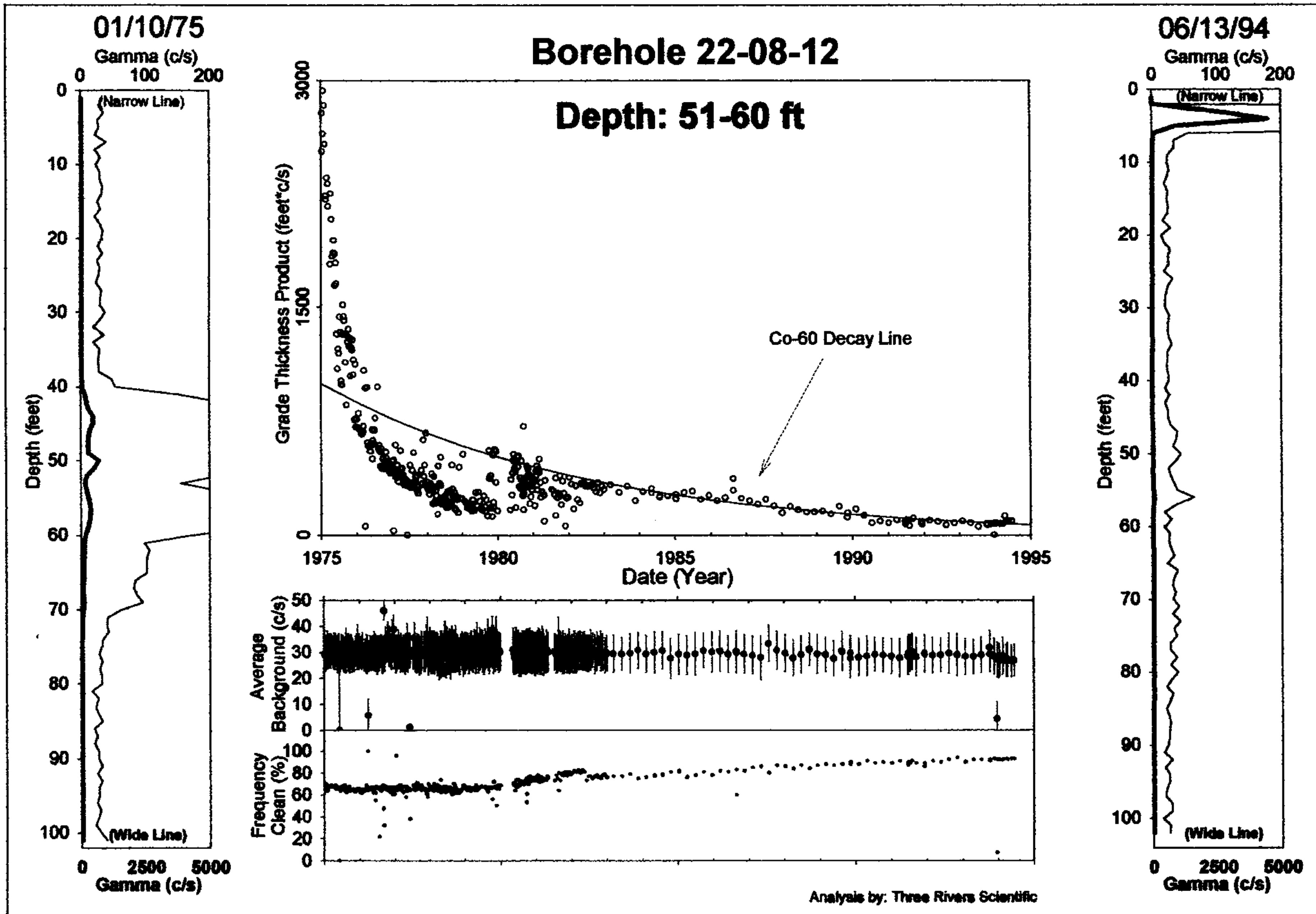
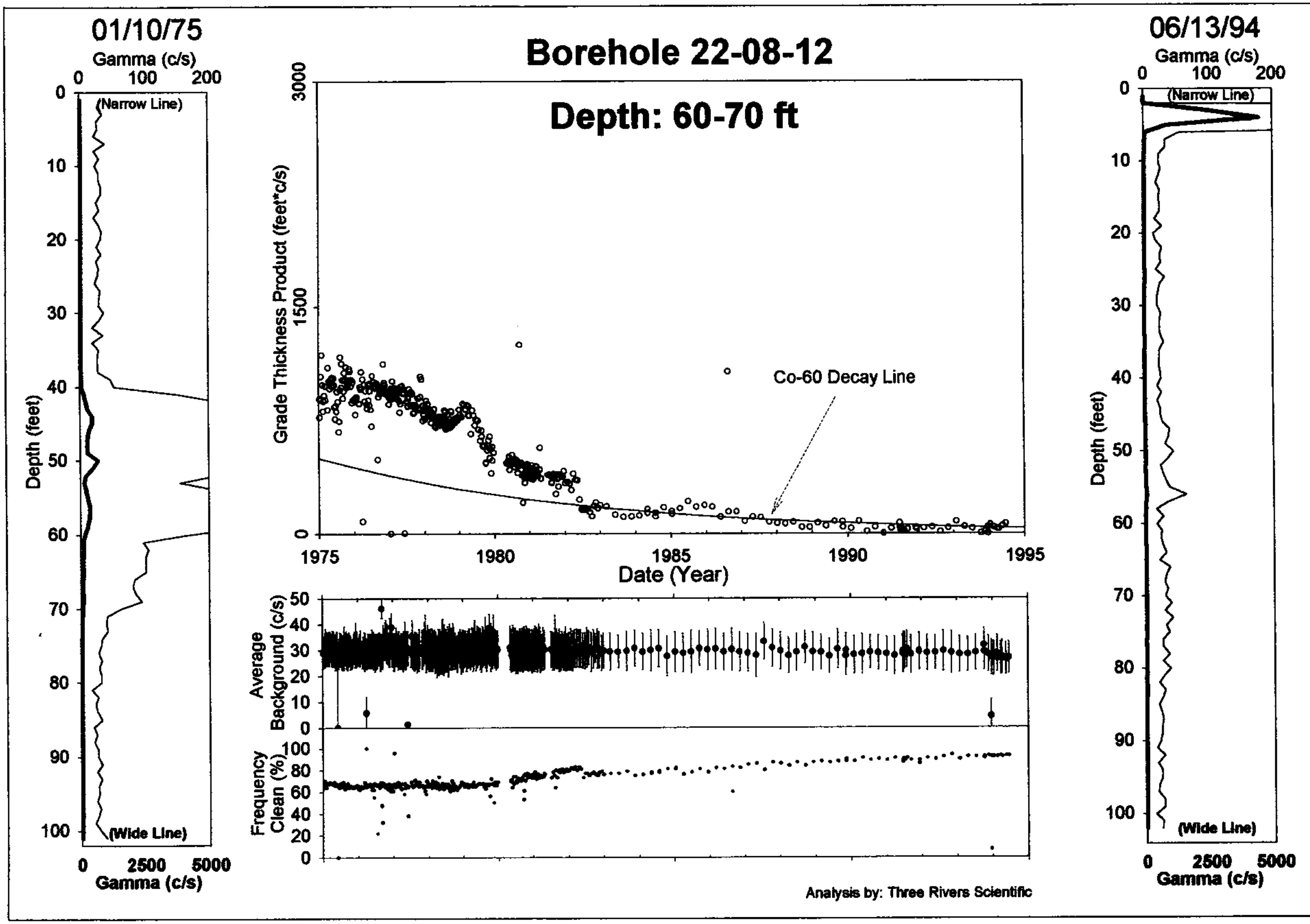
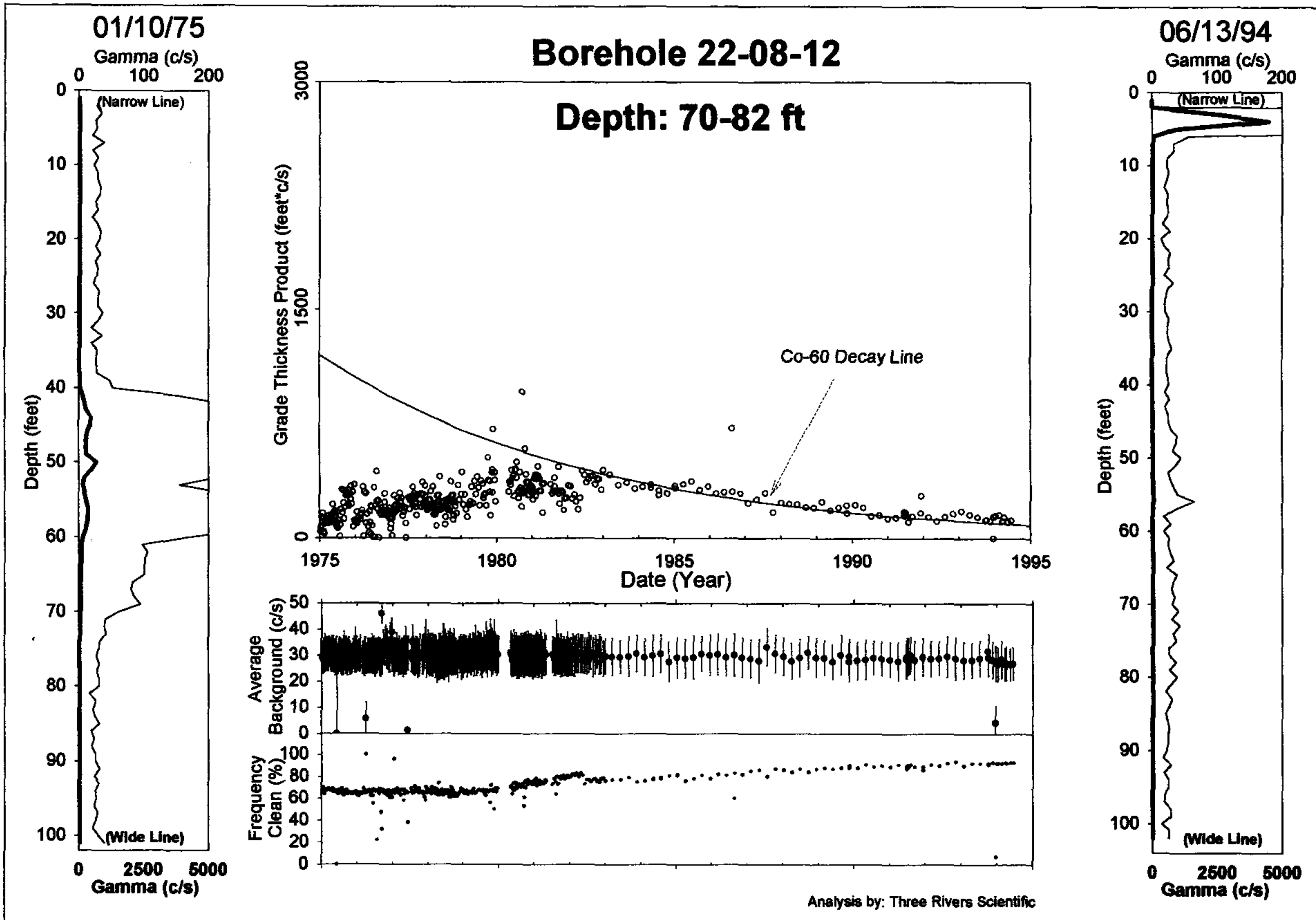


01/10/75
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
(Wide Line)
0 2500 5000
Gamma (c/s)
Borehole 22-08-12
Depth: 51-60 ft
Grade Thickness Product (feet*c/s)
0 1500 3000
Co-60 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
06/13/94
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
(Wide Line)
0 2500 5000
Gamma (c/s)



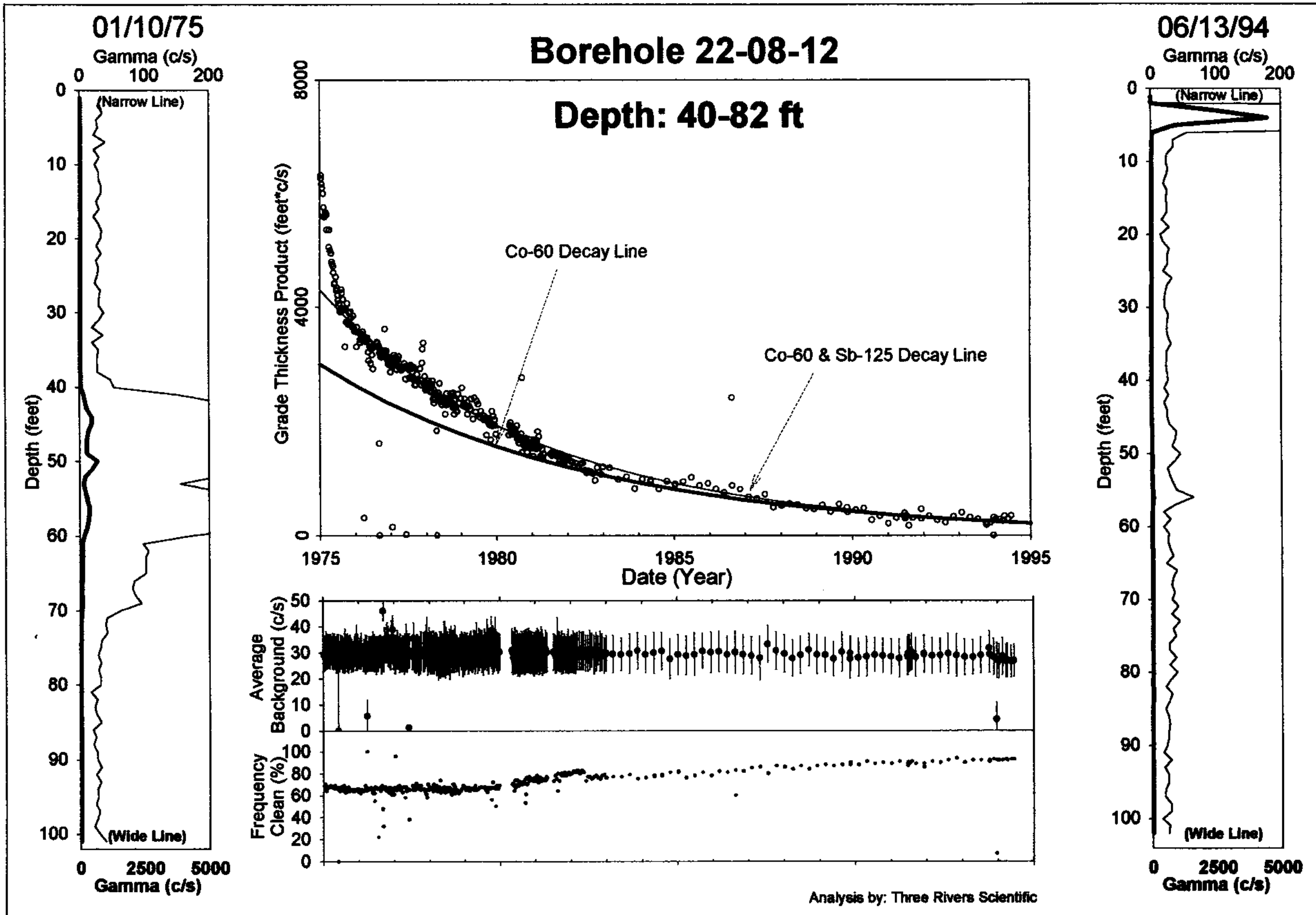
00 405

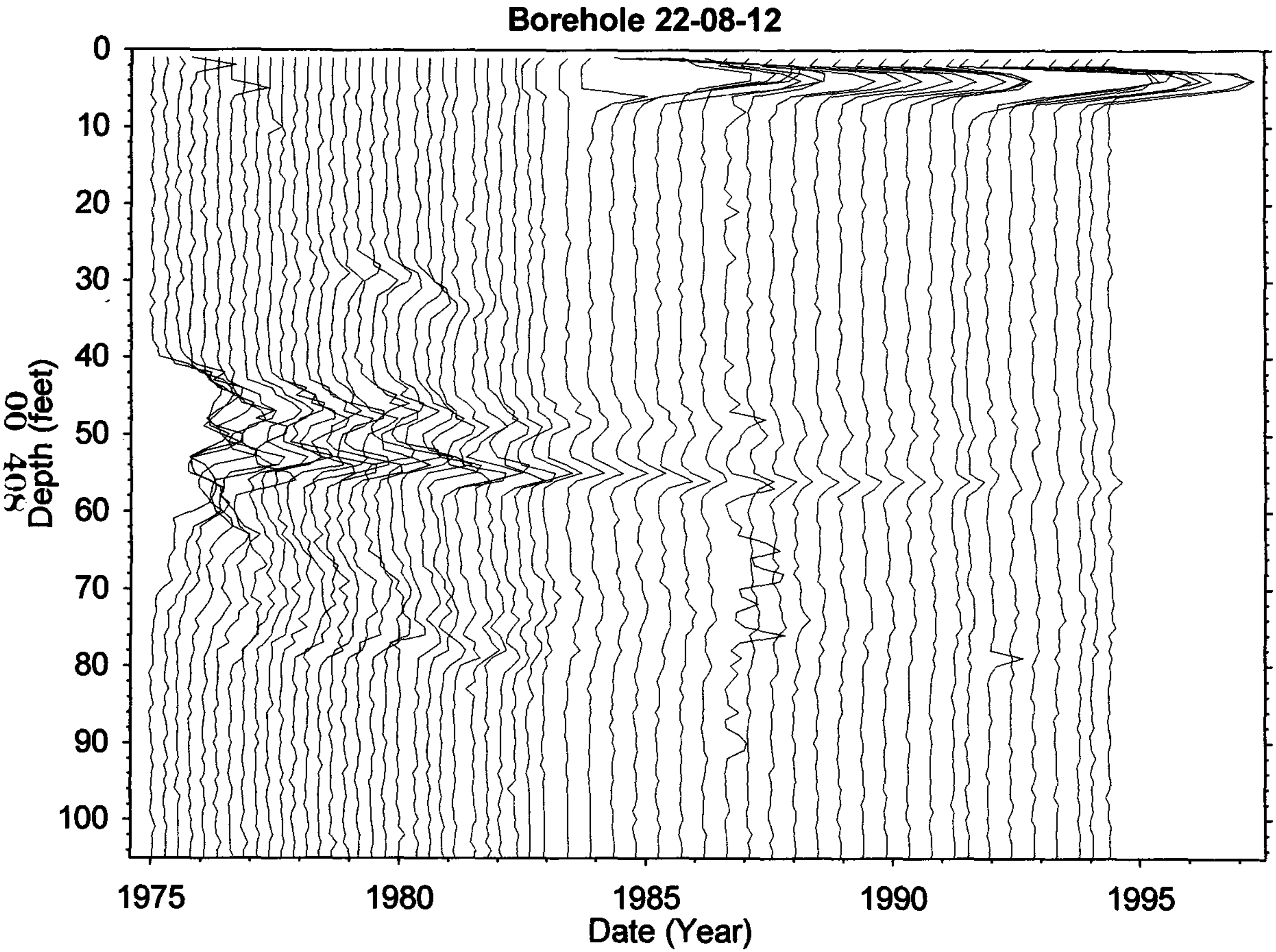
HNF-3532 -REV0

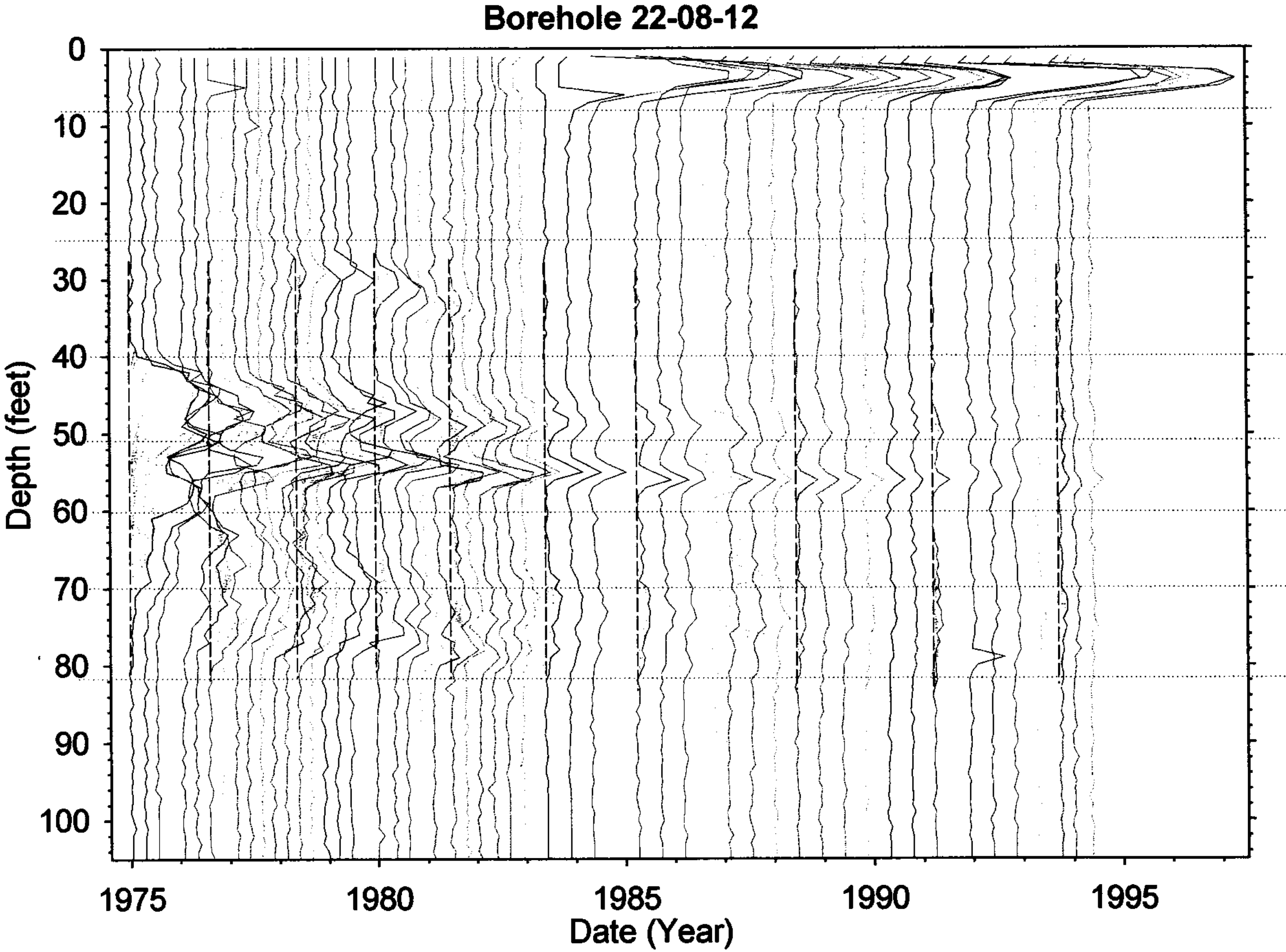


HNF-3532 -REV0

00 406


01/10/75
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
(Wide Line)
0 2500 5000
Gamma (c/s)
Borehole 22-08-12
Depth: 40-82 ft
Grade Thickness Product (feet*c/s)
0 4000 8000
Co-60 Decay Line
Co-60 & Sb-125 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
06/13/94
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
(Wide Line)
0 2500 5000
Gamma (c/s)


Borehole 22-08-12
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
Date (Year)
1975
1980
1985
1990
1995



HNF-3532 -REV0

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Dry Well Survey Analysis - Notes

Borehole BY (22-08-01) Total # Surveys 3/4 Probe Type 04
neutron surveys 2 # GR Surveys 3/2
Log Date: 75-01-09 1st 94-06-13 Last Presentation Plot Dates ______
(If different from 1st & Last)
Isotope from Spectral Survey: CS (>3000 p Ci/g) Co (27-100') Max Survey Depth 100'
Contamination Zone Depth(s): 0-12, 22-32, 32-42, 42-57, 59-82, 92-95

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-07-21	41	95	
80-09-18	22	80	
93-12-17	26	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
76-06-05	HI BKG	95	
76-07-21	BAD SURVEY	95	
78-04-06	BAD SURVEY	60	
93-12-17	NO RAD 60'	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
76-07-21	% CLEAN	95	21%	33.8	
76-09-09	AVG BKG	98	29%	42.1	
78-04-06	LENGTH	63	46%	30.6	
79-10-03	AVG BKG	98	30%	44.3	
80-09-18	% CLEAN	86	25%	30.1	
81-08-17	% CLEAN	98	27%	34.6	
83-01-03	% CLEAN	96	33%	33.1	
93-12-17	AVG BKG	98	68%	11.0	

Analysis Notes

num surveys rejected: (0) ZERO Background = ~~(0<val<50)~~ 12-22
ZONE 23-32', FIT TO GTP Co60=50, SB=400 @ 1/1/75, RATIO Co/Sb = 3.16/2.09 @ 1/1/96
ZONE 32-42', FIT TO GTP Co60=800, SB125=1400 @ 1/1/75, RATIO Sb/Co = 2.31/50.53 @ 1/96
ZONE 23-95' (COMBINED) FIT Co=15000/SB=25,000 @ 1/1/75, RATIO Sb/Co = 947/130 @ 1/1996
Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall [illegible] S/W ver (TFGROSS) ______.

filein := "two42-59.txt" **Well 22-08-01**

A := READPRN(filein) yr := $A^{<1>}$ net := $A^{<7>}$ bkg := $A^{<6>}$ max := $A^{<4>}$

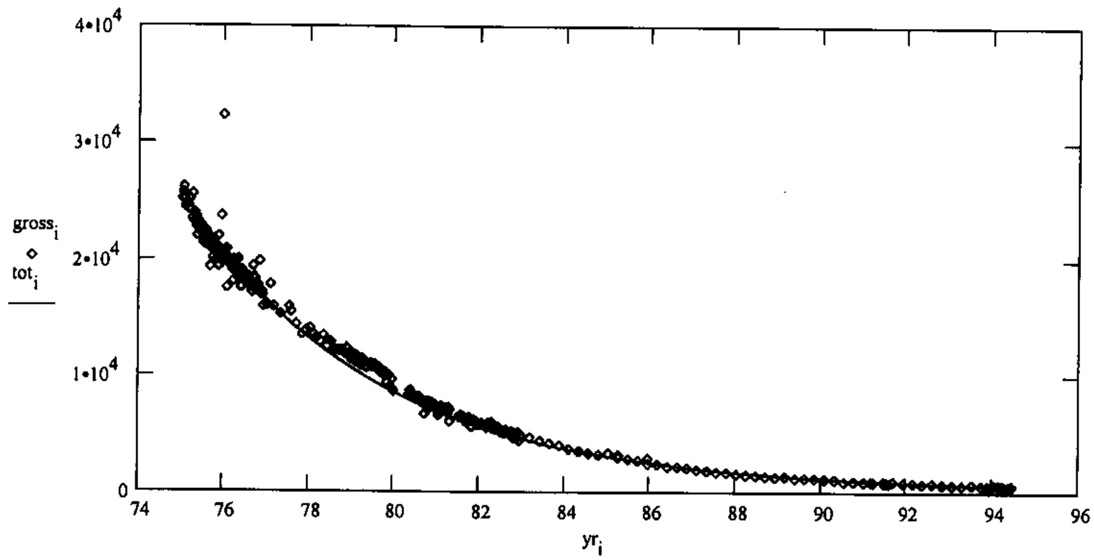
N := last(yr) N = 308 i := 0..N k := 0..300 j := 0..299

1st Isotope is Co (5.27 yrs) $\tau co := 5.27$ aco := 5000

2nd Isotope is Sb-125 (2.77 yrs) $\tau 2 := 2.77$ a2 := 21000

$Co_i := aco\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := a2\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$gross_i := net_i$ This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}\right]\right]^2$$

Given

$ssq(aco,a2) = 0$ $1 = 1$

$$\begin{bmatrix}\alpha co \\ \alpha 2\end{bmatrix} := Minerr(aco,a2)$$

$\alpha co = 6.202\cdot 10^3$ Sb $\alpha 2 = 1.952\cdot 10^4$

$Co_i := \alpha co\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := \alpha 2\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$ $\frac{\alpha co}{\alpha 2} = 0.318$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop.txt") := out Ratio Sb/Co $\frac{X2_N}{Co_N} = 0.313$

22-32 FT Sb/Co = 0.66 (1996)
32-42 FT Sb/Co = 0.14 (1996)

filein := "two59-82.txt" **Well 22-08-01**

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

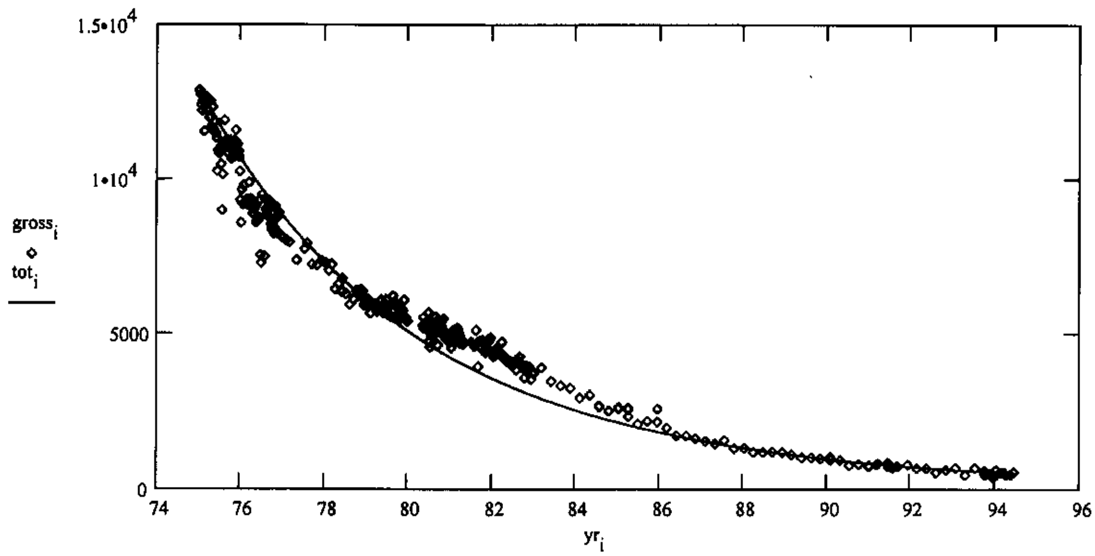
N := last(yr) N = 308 i := 0.. N k := 0.. 300 j := 0.. 299

1st Isotope is Co (5.27 yrs) $\tau co := 5.27$ aco := 6000

2nd Isotope is Sb-125 (2.77 yrs) $\tau 2 := 2.77$ a2 := 7000

$Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := a2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$gross_i := net_i$ This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}} \right] \right]^2$$

Given

ssq(aco, a2) = 0 1 = 1

$$\begin{bmatrix} \alpha co \\ \alpha 2 \end{bmatrix} := Minerr(aco, a2)$$

$\alpha co = 8.634 \cdot 10^3$ Sb $\alpha 2 = 3.401 \cdot 10^3$

$Co_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := \alpha 2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$ $\frac{\alpha co}{\alpha 2} = 2.539$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop.txt") := out Ratio Sb/Co $\frac{X2_N}{Co_N} = 0.039$

Dry Well Survey Analysis - Notes

Borehole BY(22-08-02) Total # Surveys 307 Probe Type 04
\# neutron surveys 2 # GR Surveys 305
Log Date: 75-01-09 1st 94-06-13 Last Presentation Plot Dates
(If different from 1st & Last)
Isotope from Spectral Survey: Max Survey Depth 100
Contamination Zone Depth(s): 0-10, 20-30, 44-62, 62-72, 72-84, 84-100

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
80-09-18	29	95	
81-04-30	97	95	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-06-05	HI-BKG	100	
76-01-22	LONG SURVEY	170	
80-09-24A	BAD LOG	100	
81-04-30	WRONG HOLE	95	
82-01-07A	BAD LOG	50	
RAD ZONE - DEPTH	STEP CHG. (5/1-82 TO 6-2-82) - 4' BERM ADDED		

93-12-17 TOOL FAIL 100

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-06-05	% CLEAN	98	0%	0.0	
75-09-10	% CLEAN	98	22%	41.7	
76-09-09	AVG BKG	97	27%	40.4	
76-10-15	AVG BKG	97	25%	42.3	
81-04-30	% CLEAN	97	0%	0.0	
85-12-12	AVG BKG	102	90	12.5	
93-12-17	% CLEAN	101	13%	35.4	

Analysis Notes

num surveys rejected: (0) ZERO Background = (0<~~val~~<50) 10-28 FT
TF ACTIVITY

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V2.20.

filein := "GTP44-100.txt" **Well 22-08-02**

A := READPRN(filein) $\quad yr := A^{\langle 1\rangle} \quad net := A^{\langle 7\rangle} \quad bkg := A^{\langle 6\rangle} \quad max := A^{\langle 4\rangle}$

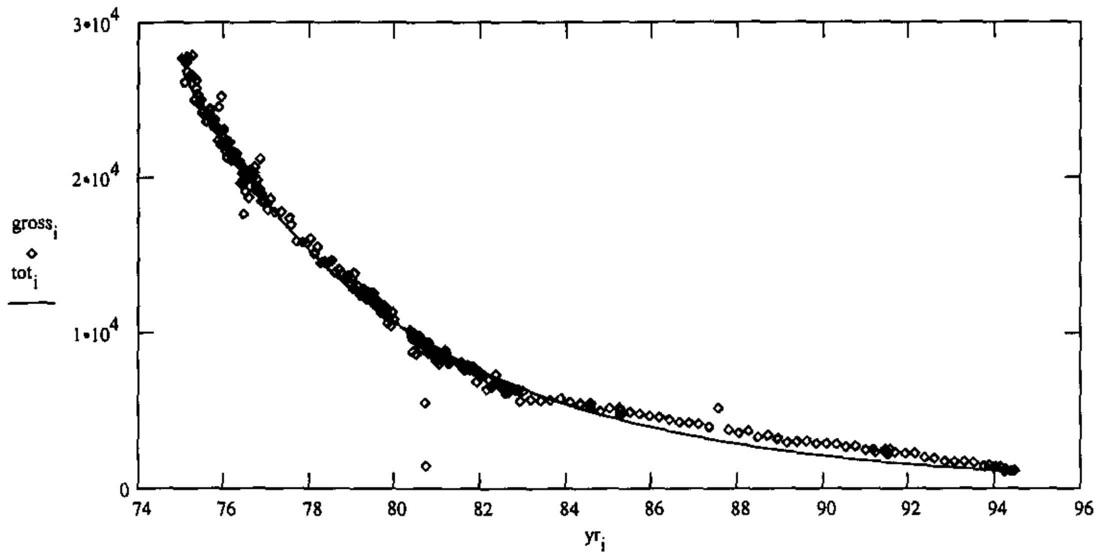
$N := last(yr) \quad N = 300 \quad i := 0..N \quad k := 0..300 \quad j := 0..299$

1st Isotope is Co (5.27 yrs) $\quad \tau co := 5.27 \quad aco := 13000$

2nd Isotope is Sb (2.77 yrs) $\quad \tau 2 := 2.77 \quad a2 := 14000$

$Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \qquad X2_i := a2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}} \qquad tot_i := Co_i + X2_i$

$gross_i := net_i$ This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}\right]\right]^2$$

Given

$ssq(aco,a2) = 0 \qquad 1 = 1$

$\begin{bmatrix}\alpha co\\ \alpha 2\end{bmatrix} := Minerr(aco,a2)$

$\boxed{\alpha co = 1.304\cdot 10^4 \quad \text{Co-60}} \qquad \boxed{\alpha 2 = 1.417\cdot 10^4 \quad \text{Sb-125}} \qquad \frac{\alpha co}{\alpha 2} = 0.92$

$Co_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \qquad X2_i := \alpha 2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}} \qquad tot_i := Co_i + X2_i$

$out^{\langle 0\rangle} := yr \qquad out^{\langle 1\rangle} := tot \qquad$ WRITEPRN("twop.txt") := out $\qquad \boxed{\text{Ratio Co/Sb} \quad \frac{Co_N}{X2_N} = 9.261}$

filein := "GTP20-30.txt" **Well 22-08-02**

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

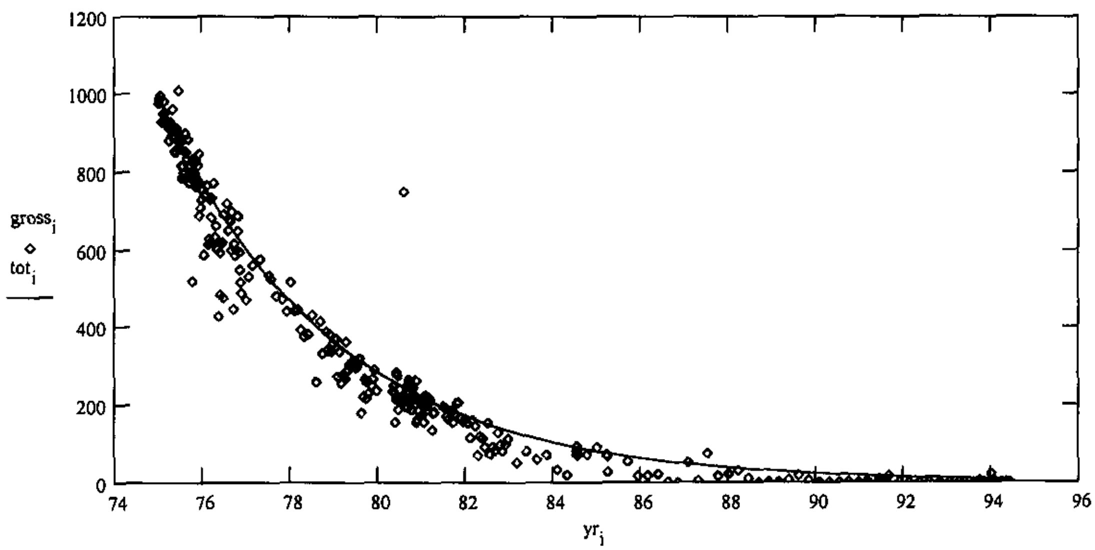
N := last(yr) N = 290 i := 0..N k := 0..300 j := 0..299

1st Isotope is Co (5.27 yrs) $\tau co := 5.27$ aco := 0

2nd Isotope is Sb (2.77 yrs) $\tau 2 := 2.77$ a2 := 1000

$Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := a2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$gross_i := net_i$ This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}\right]\right]^2$$

Given

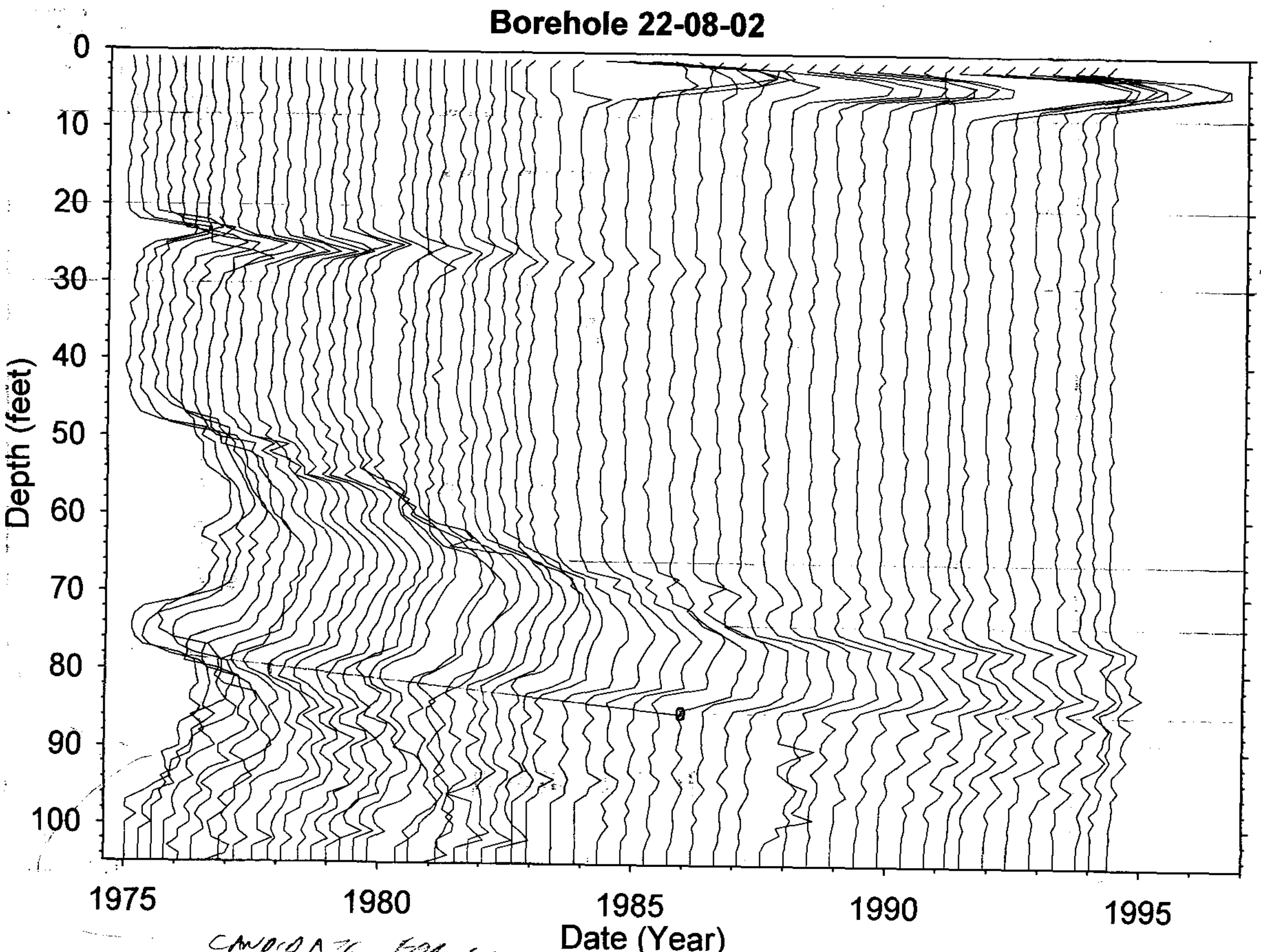
ssq(aco, a2)=0 1=1

$\begin{bmatrix}\alpha co\\ \alpha 2\end{bmatrix}$:= Minerr(aco, a2)

$\alpha co = -53.762$ Co-60 $\alpha 2 = 1.014\cdot10^3$ Sb-125 $\frac{\alpha co}{\alpha 2} = -0.053$

$Co_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := \alpha 2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop.txt") := out Ratio Co/Sb $\frac{Co_N}{X2_N} = -0.534$



CANDIDATE FOR CASING [illegible]

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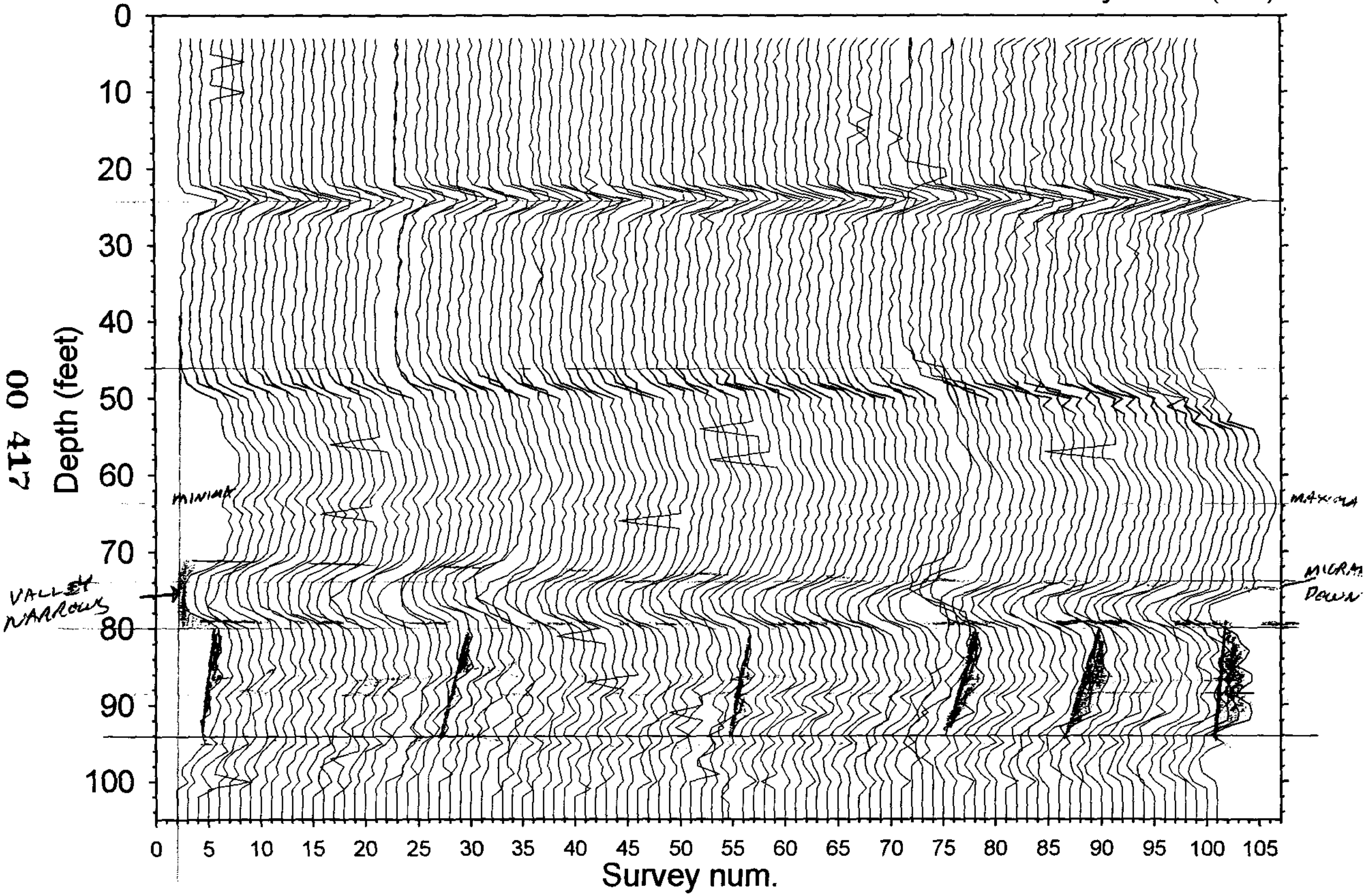
Borehole 22-08-02 Survey start 0 (100)

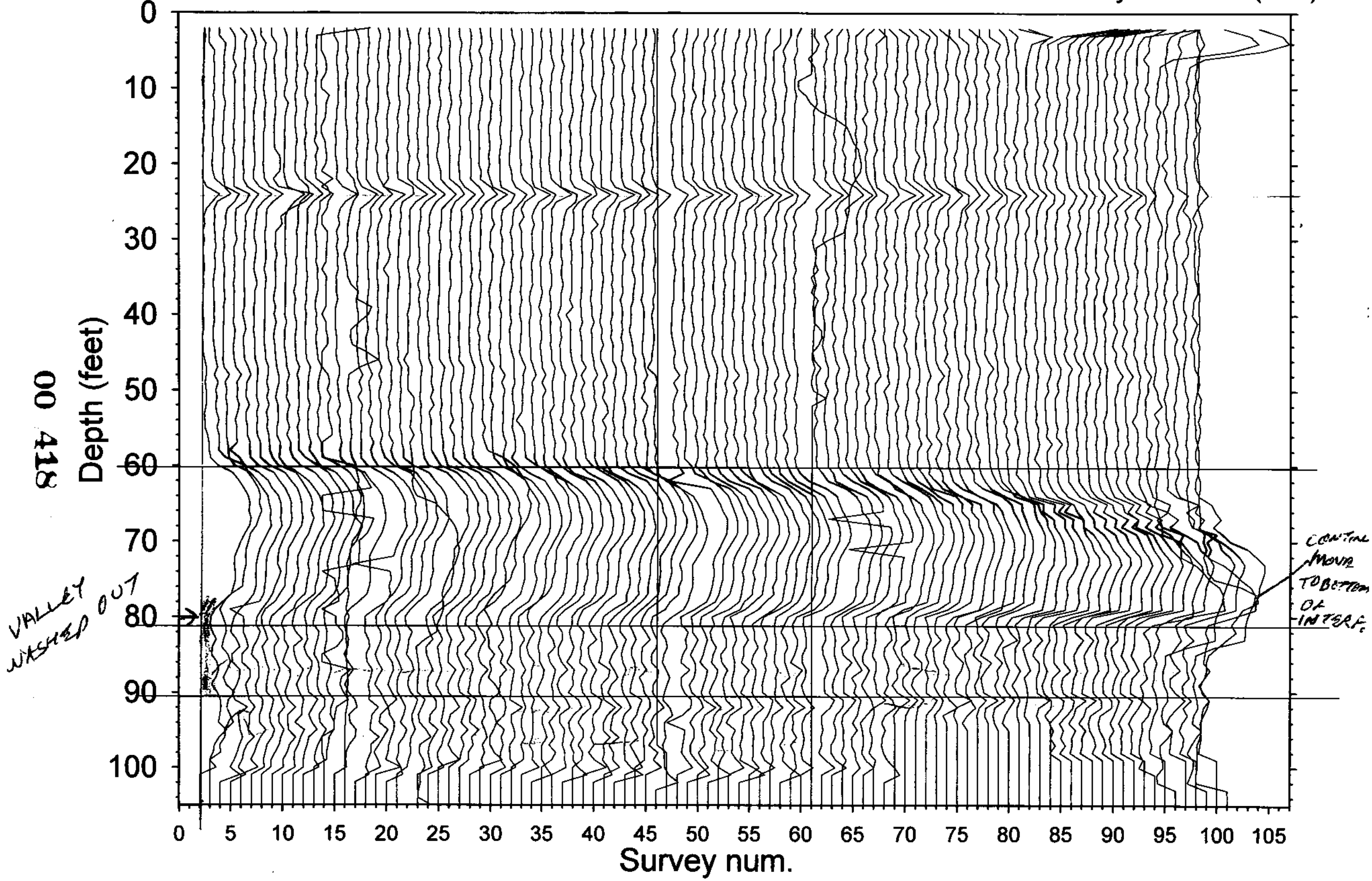


00 417

HNF-3532 -REV0

Borehole 22-08-02

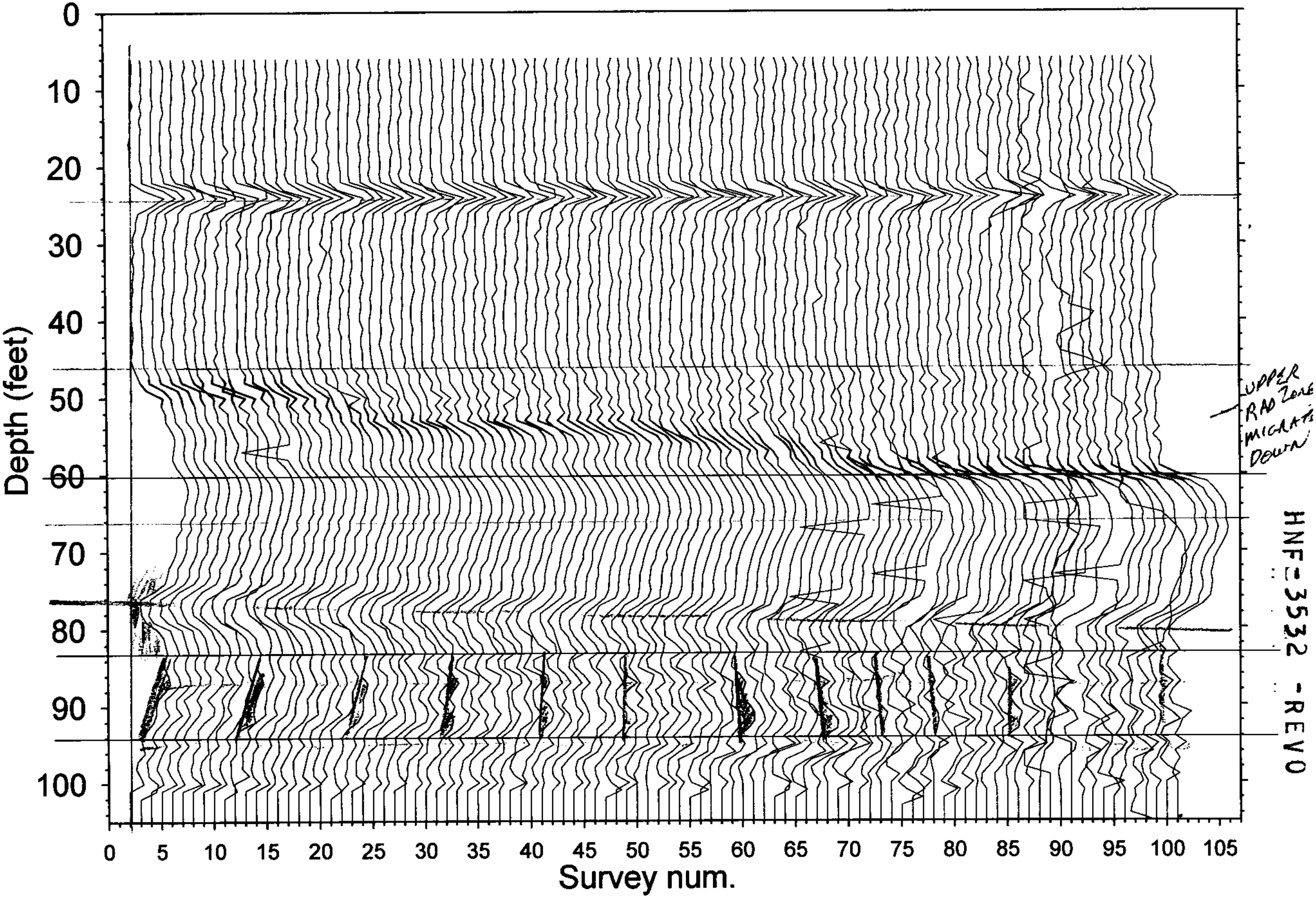
Survey start 150 (100)



HNF-3532 -REV0

00 418

Borehole 22-08-02 Survey start 75 (100)

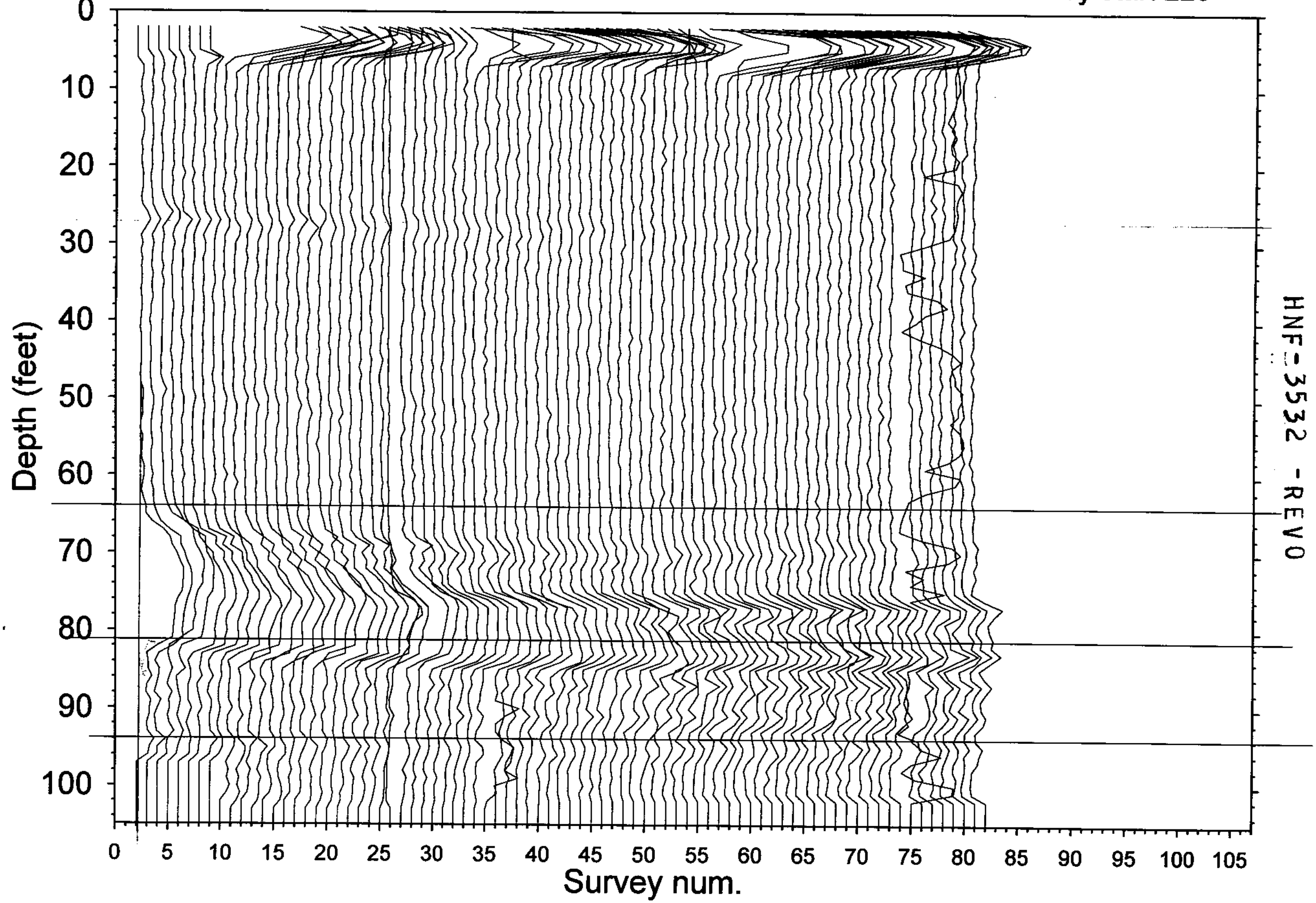


00 419

HNF-3532 -REV0

Borehole 22-08-02

Survey start 225



HNF-3532 -REV0

Dry Well Survey Analysis - Notes

Borehole BYC 22-08-05 Total # Surveys 318 Probe Type 04

\# neutron surveys 4 # GR Surveys 314

Log Date: 75-01-09 [st] 94-06-13 Last Presentation Plot Dates

(If different from 1[st] & Last)

Isotope from Spectral Survey: CS CO (38-81 FT) Max Survey Depth 100

Contamination Zone Depth(s): 0-8, 36-45, 45-53, 53-63, 63-74, 74-84

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-09-02A,B	32	102	
78-09-13	20	100	
80-09-18	9	95	
81-10-26	9	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-03-12	HI-BKG	100	
75-05-08	WRONG HOLE	170	PROBABLY TOOL FAIL
76-08-19A	NO RAD PEAK	140	
77-08-03	TOOL FAIL	105	
78-11-01	HI-BKG	100	
90-02-02A	TOOL FAIL	100	

91-12-06A BAD LOC

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-03-12	%CLEAN	99	26%	38.0	
75-05-08	LENGTH	201	60%	33.9	
76-09-30	AVG BKG	96	68%	36.9	
77-08-03	AVG BKG	100	59%	37.8	
78-11-01	AVG BKG	97	32%	43.8	
79-10-30	AVG BKG	95	69%	37.4	
90-02-02	% CLEAN	97	0%	0.0	
94-03-24	AVG BKG	97	95%	8.4	

Analysis Notes

num surveys rejected: (0) ZERO	Background = (~~0<val<50~~) 10-35
Category: (Stable, TF Activity, Undetermined, CHANGED	

Analyst Name Randall Price S/W ver (TFGROSS) V2.20.

Dry Well Survey Analysis - Notes

Borehole BY(22-08-06) Total # Surveys 316 Probe Type 04
neutron surveys 2 # GR Surveys 314
Log Date: 75-01-09 1st 94-06-13 Last Presentation Plot Dates
(If different from 1st & Last)
Isotope from Spectral Survey: CS CO (64-95FT) Max Survey Depth 100
Contamination Zone Depth(s): 0-8, 8-18, 18-29, 46-54, 54-63, 63-73, 73-83, 83-9

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-04-29	33	90	94-03-24 93, 100'
76-07-28	61	90	94-04-06A 78, 100
78-09-13	22	90	
80-09-18	18	90	
81-10-26	10	95	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-03-12	HI-BKG	102	
75-11-12A	BAD SURVEY	50	
76-05-20	TOOL FAIL	100	
76-07-28	BAD SURVEY	90	
78-11-01	HI-BKG	100	
91-02-16	HI-BKG	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-03-12	% CLEAN	102	26%	41.8	
75-06-26	% CLEAN	98	46%	37.9	
76-05-20	% CLEAN	98	0%	0.0	
77-05-05	AVG BKG	98	57%	40.0	
78-11-01	AVG BKG	100	24%	43.7	
79-10-03	AVG BKG	98	13%	46.2	
91-02-16	% CLEAN	98	37%	38.5	
94-04-06	% CLEAN	98	20%	1.5	

Analysis Notes

num surveys rejected: (0) ZERO Background = (0<val<50) 30-46FT
ZONE: 46-54FT, FIT TO GTP Co/Cs = 7% @ 1/1/77, RATIO Co/Cs = 4.42/12.35 = 0.36 @ 1/96

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V 2.20.

filein := "GTP46-83.txt"

Well 22-08-06

$A := \mathrm{READPRN}(\mathrm{filein})$ $\quad yr := A^{\langle 1 \rangle}$ $\quad net := A^{\langle 7 \rangle}$ $\quad bkg := A^{\langle 6 \rangle}$ $\quad max := A^{\langle 4 \rangle}$

$N := \mathrm{last}(yr)$ $\quad N = 298$ $\quad i := 0..N$ $\quad k := 0..300$ $\quad j := 0..299$

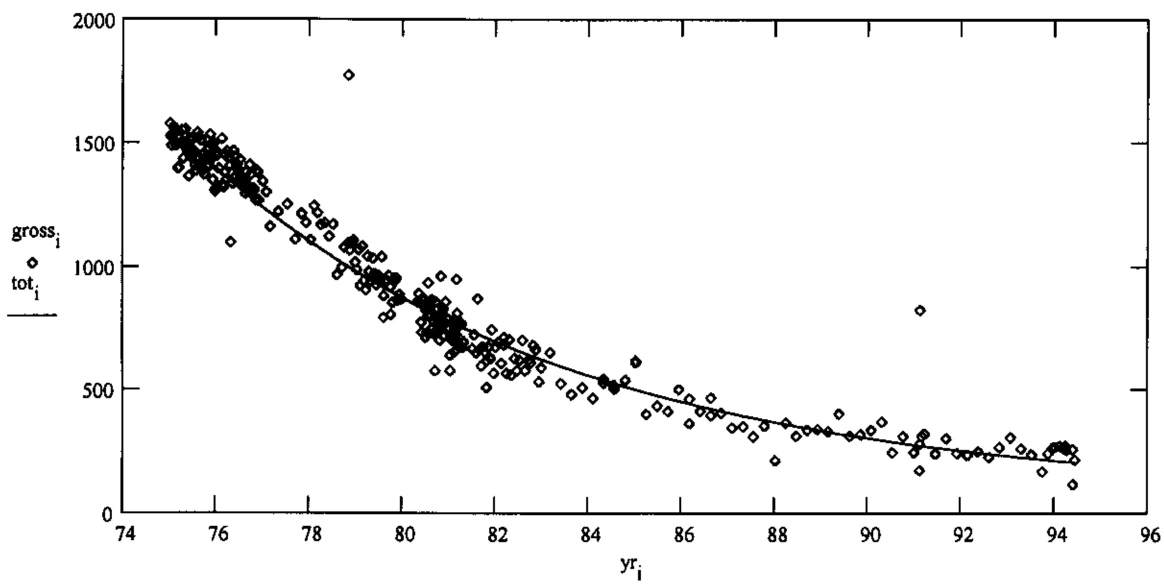
$\tau cs := 30.17$ $\quad acs := 150$

$\tau co := 5.27$ $\quad aco := 1430$

$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $\quad Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $\quad tot_i := Cs_i + Co_i$

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}\right]\right]^2$$

Given

$ssq(acs, aco) = 0$ $\quad 1 = 1$

$$\begin{bmatrix} \alpha cs \\ \alpha co \end{bmatrix} := \mathrm{Minerr}(acs, aco)$$

$\alpha cs = 150.188$ $\quad \alpha co = 1.439 \cdot 10^3$

$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}}$ $\quad Eu_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $\quad tot_i := Cs_i + Co_i$ $\quad \frac{\alpha cs}{\alpha co} = 0.104$

$out^{\langle 0 \rangle} := yr$ $\quad out^{\langle 1 \rangle} := tot$ $\quad \mathrm{WRITEPRN}(\text{"twop.txt"}) := out$ $\quad \frac{Co_N}{Cs_N} = 1.153$

1-ZONE 0-8 FT
TF ACTIV

Dry Well Survey Analysis - Notes

Borehole BY (22-08-07)
Total # Surveys 301
Probe Type 04
neutron surveys 5
GR Surveys 296
Log Date: 75-01-09 1st
94-06-13 Last
Presentation Plot Dates
(If different from 1st & Last)
Isotope from Spectral Survey: Cs <8 pCi/g (40-100')
Max Survey Depth 125
Contamination Zone Depth(s): 0-8, 40-70, 70-90, 90-100, 100-120 CLEAN ZONE

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-07-28	72	140	
80-09-17	20	130	
84-05-03	24	135	
93-12-01	129	130	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-03-12	HI-BKG	140	
76-05-20A	TOOL FAIL	140	
76-07-21	PEAK AT 0'	140	
78-11-01	HI-BKG	140	
80-10-29	HI-BKG	140	
81-07-14	HI-BKG	140	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-03-12	AVG BKG	140	60%	322	
76-05-20	% CLEAN	137	20%	345	
78-11-01	AVG BKG	136	83%	40.6	
80-10-29	% CLEAN	137	66%	44.8	
92-11-03	LENGTH	178	100%	23.9	
93-04-21	LENGTH	300	99%	24.0	
93-12-01	% CLEAN	132	2%	4.7	

Analysis Notes

num surveys rejected: (0) ZERO
Background = (0<val<50) 20-40 FT
REVIEW OF RADIATION? ZONES (40-70, 70-90, 90-100, 100-120)
CONFIRM VERY LOW LEVEL ACTIVITY ABOVE BKG (20-40')
AND (EXCEPT FOR SHORT LIVED ZONE (70-90 FT) FROM 1975 TO 1976)
NO SIGNIFICANT QUANTITIES OF RADIATION ARE PRESENT OR
ABRUPTLY INTRODUCED INTO THE ZONES
* 0-8 FT : TF ACTIVITY
Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price
S/W ver (TFGROSS) V2.20

Dry Well Survey Analysis - Notes

Borehole B4(22-08-09) Total # Surveys 405 Probe Type 04

\# neutron surveys 2 # GR Surveys 403

Log Date: 75-01-10 1st 94-06-13 Last Presentation Plot Dates ______
(If different from 1st & Last)

Isotope from Spectral Survey: CS-137 Max Survey Depth 100

Contamination Zone Depth(s): 0-10FT, 72-84

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-07-28	48	80	
76-09-03	19	95	
77-06-02	89	95	
94-03-24	93	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-06-05	HI BKG	100	
76-03-18	NOISE	100	
76-10-15	TOOL FAIL	95	
77-04-14	HI-BKG	100	
77-10-27	WRONG HOLE	95	
86-08-22	NOISE	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-06-05	% CLEAN	99	0%	0.0	
76-03-18	% CLEAN	100	66%	29.8	
77-06-02	% CLEAN	98	9%	20.3	
78-03-22	AVG BKG	97	27%	11.5	
80-10-29	% CLEAN	99	54%	44.3	
86-08-22	% CLEAN	99	68%	25.3	
93-10-04	LENGTH	173	94%	33.0	
94-03-24	% CLEAN	98	3%	13.7	

Analysis Notes

num surveys rejected: (0) ZERO Background = (0<val<50) 50 - 70

0-10FT: TF ACTIVITY

72-84FT: LOW LEVEL RAD ZONE, INCR 1975 TO 1976, THEN DECREASE >CS-137 DECAY 1976 TO 1978

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V 2.20.

Dry Well Survey Analysis - Notes

Borehole BY(22-08-12 Total # Surveys 383 Probe Type 04
neutron surveys 3 # GR Surveys 380
Log Date: 75-01-10 1st 94-06-13 Last Presentation Plot Dates ______
(If different from 1st & Last)
Isotope from Spectral Survey: ______ Max Survey Depth 105
Contamination Zone Depth(s): 0-8, 25-40, 40-51, 51-60, 60-70, 70-82

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-07-21	28	85	
76-09-03	28	90	
77-06-02	60	100	
80-09-18	22	95	
93-12-17	94	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-06-05	HI-BKG	100	
76-03-25	NO RADZONE	100	
76-07-21	TOOL FAIL	80	
78-04-20	BAD SURVEY	40	
80-09-24	NOISE	100	
86-08-22	HI-NOISE	100	

3FT DEPTH CHG (82-05-11 TO 82-06-02)

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-06-05	% CLEAN	100	0 %	0.0	
76-03-25	AVG BKG	98	100 %	5.8	
76-09-09	% CLEAN	100	32 %	46.1	
77-06-02	% CLEAN	98	38 %	1.4	
78-04-20	LENGTH	41	63 %	271	
79-11-14	AVG BKG	99	50 %	36.2	
80-09-18	% CLEAN	96	53 %	30.6	
93-12-17	% CLEAN	102	7 %	4.4	

Analysis Notes

num surveys rejected: (0) ZERO	Background = (0<~~val~~<50) 10-24
DEPTH SHIFT ~~NOT~~ IF POSSIBLE	
25-40FT : INCREASE 1979-1982	RATIO Sb/Co = 1391/3002 1995
40-51 FT : RAPID DECREASE - SHOW MATCH W/ Sb & Co DECAY	
51-60 FT : RAPID DECREASE 1975, STABLE Co-60 AFTER 1982	
60-70 FT : Co-60 DECREASE AT RATE > DECAY 1975-1983 THEN STABLE	
70-82 FT : Co-60 INGROWTH 1975 TO 1982 THEN STABLE	
Category: (Stable, TF Activity, Undetermined, CHANGED	

COMBINED GTP (0-82 FT) SHOWS SMOOTH RATE OF DECREASE (Co & Sb-125 DECAY LINE) POTTS

Analyst Name [signature] S/W ver (TFGROSS) V2.20

Borehole 22-09-01

Contamination (Ru-106) from 24 to 35 feet is Stable
Contamination (Sb-125 & Ru-106) from 40 to 55 feet is Stable

Grade Thickness Product for the radioactive zone (24-35 feet) is decreasing within observed systematic limitations at a rate consistent with Ru-106 (hypothesis) between 1975 and 1978. The gamma ray activity decreases quickly to background activities.

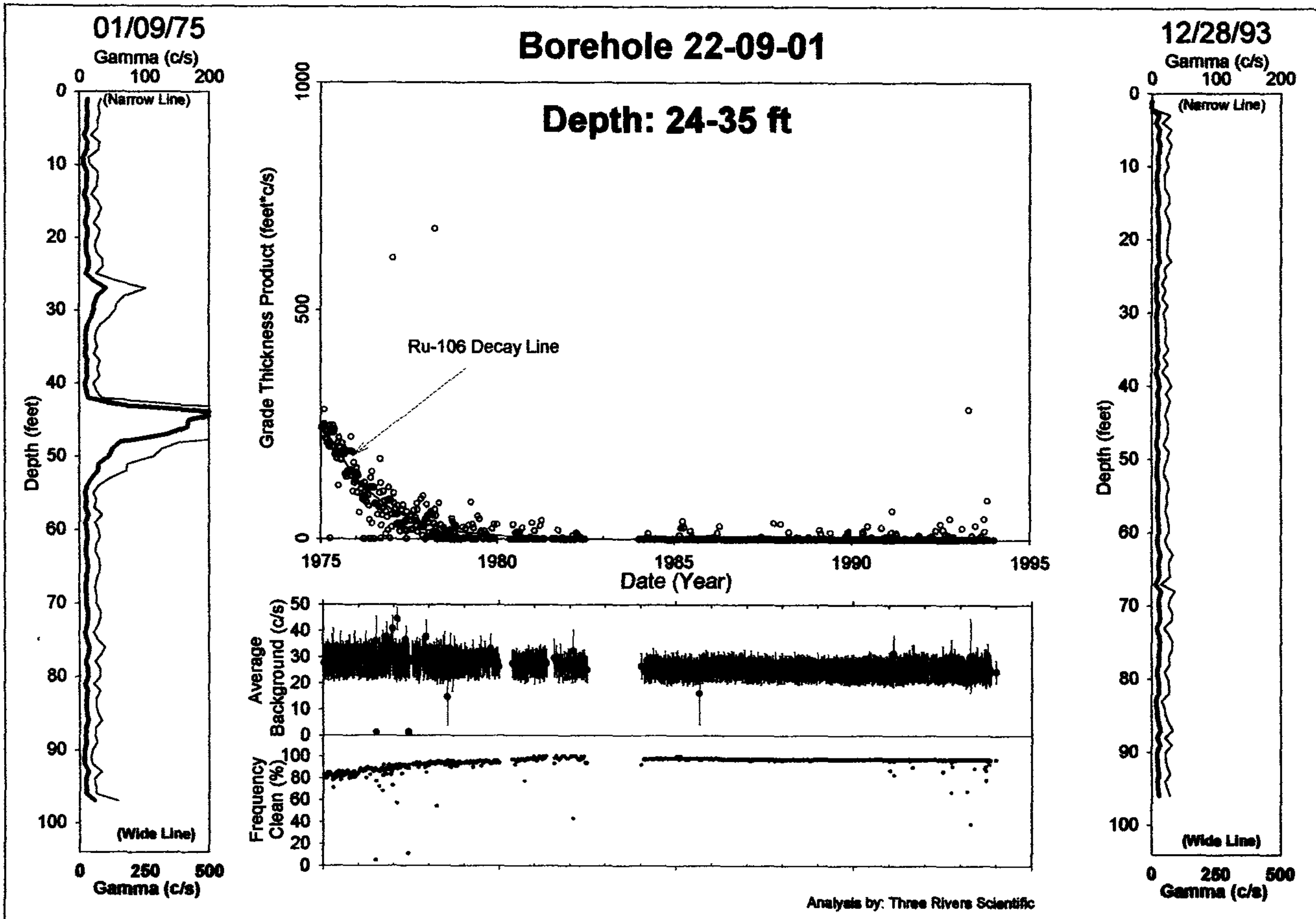
Grade Thickness Product for the radioactive zone (40-55 feet) is decreasing within observed systematic limitations and relative intensity at a rate consistent with a least squares fit of Ru-106 (hypothesis), Sb-125 (hypothesis) between 1975 and 1994. Cobalt-60 (identified from HPGe detector at low concentrations, less than 0.7 pCi/g) was not included in the least squares fit and is below the gross gamma detection threshold. When included the concentration for Co-60 resulted in a negative quantity contribution to the resultant fit. The least squares fit results in a gross gamma contribution ratio for Sb-125 to Ru-106 on January 1975 was 0.36.

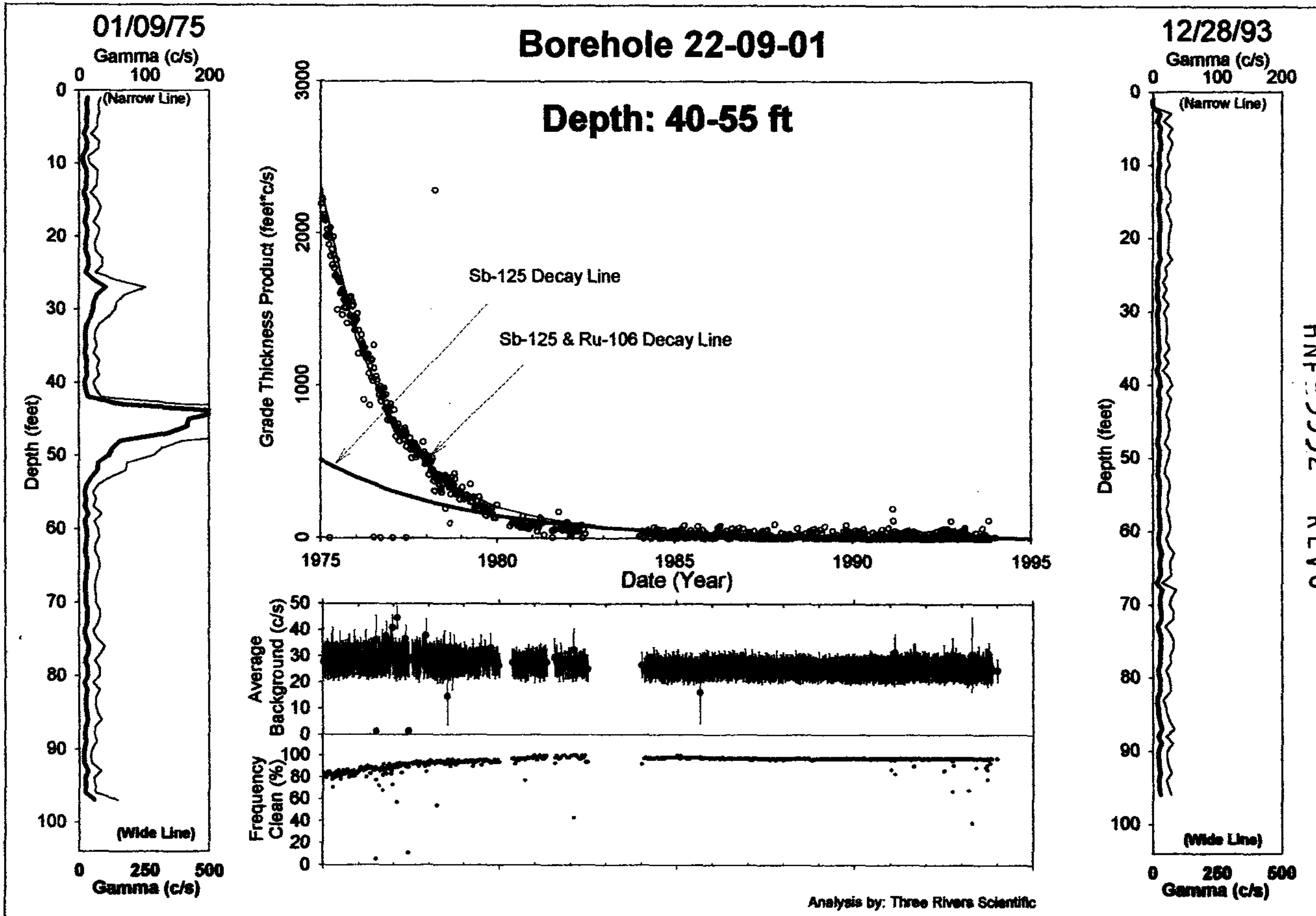
Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (6 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	12/28/1993
Number Surveys :	674

Analysis Notes

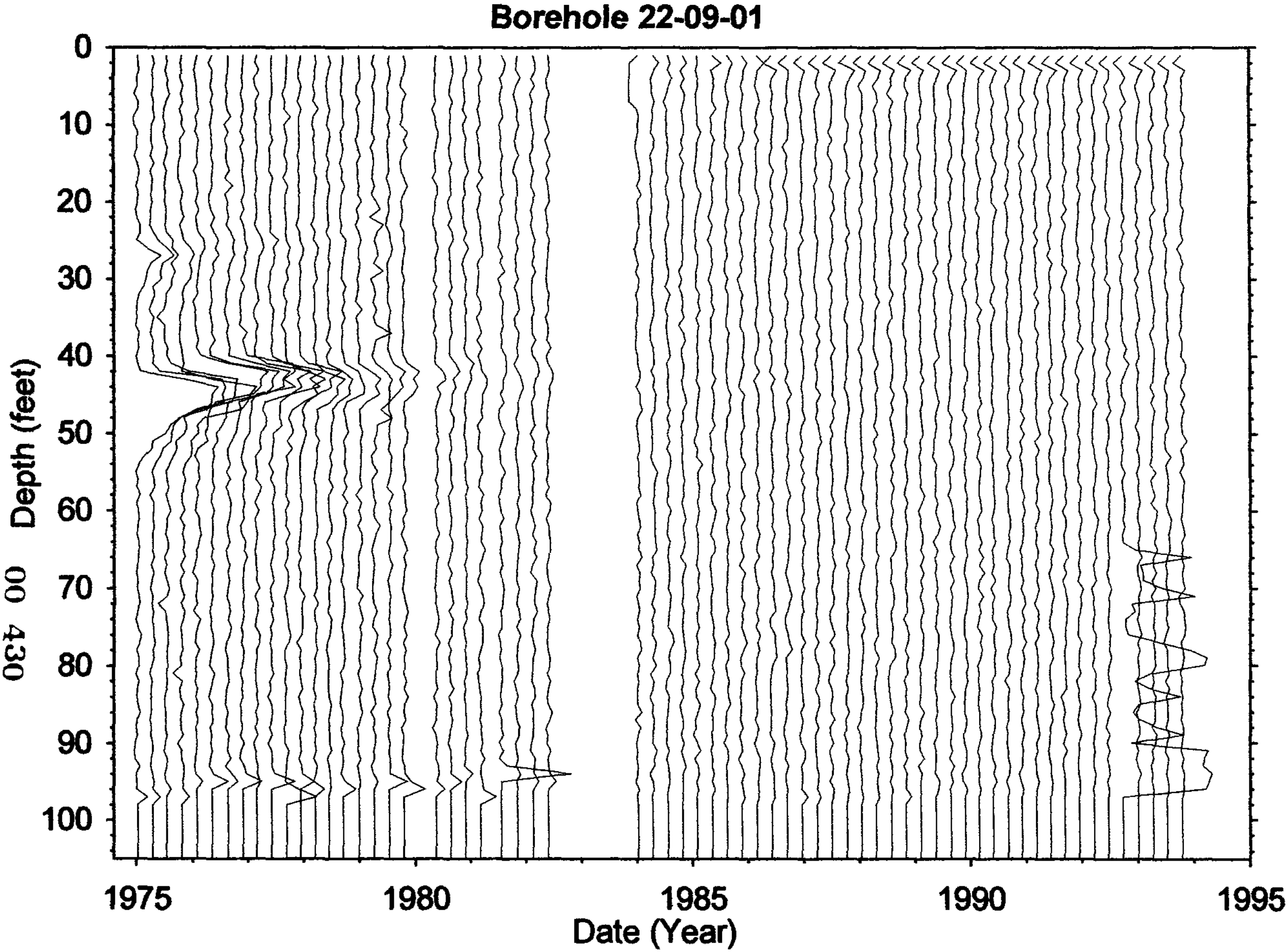
Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	10 to 20 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	24-35 feet is Stable 40-55 feet is Stable
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific


01/09/75
Gamma (c/s)
0
100
200
(Narrow Line)
Depth (feet)
(Wide Line)
0
250
500
Gamma (c/s)
Borehole 22-09-01
Depth: 24-35 ft
Grade Thickness Product (feet*c/s)
Ru-106 Decay Line
Date (Year)
1975
1980
1985
1990
1995
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
12/28/93
Gamma (c/s)
(Narrow Line)
Depth (feet)
(Wide Line)
Gamma (c/s)



01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Borehole 22-09-01
Depth: 40-55 ft
Grade Thickness Product (feet*c/s)
Sb-125 Decay Line
Sb-125 & Ru-106 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
12/28/93

00 429



HNF-3532 -REV0

030 00 430

Borehole 22-09-02

Contamination (Cs-137) from 0-10 and 10-14 feet is Tank Farm Activity
Contamination (Cs-137) from 14 to 34 feet is Stable
Contamination (Ru-106) from 42 to 64 feet is Stable

Grade Thickness Product from 0-10 and 10-14 feet is erratic from 1975 to 1986, and is categorized as Tank Farm activity. Grade Thickness Product from 1986 through 1993 is decreasing within counting statistics at a rate consistent with Cs-137 (identified from HPGe detector).

Grade Thickness Product for the radioactive zone (14-34 feet) is decreasing within the gross gamma sensitivity at a rate consistent with Cs-137 (identified from HPGe detector) between January 1975 and December 1993.

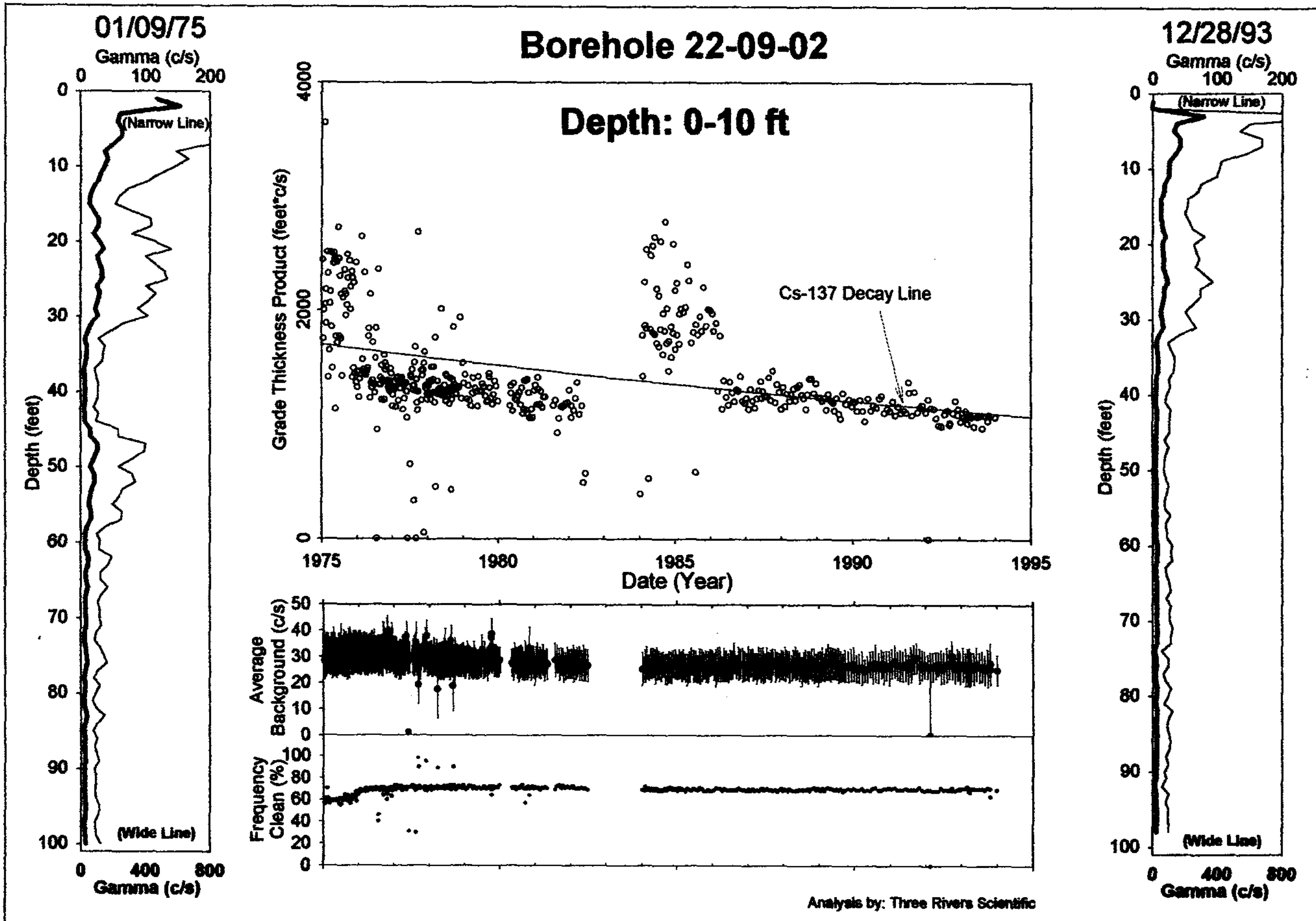
Grade Thickness Product for the radioactive zone (42-64 feet) is decreasing within the gross gamma sensitivity at a rate consistent with Ru-106 (hypothesis) from 1975 to 1982.

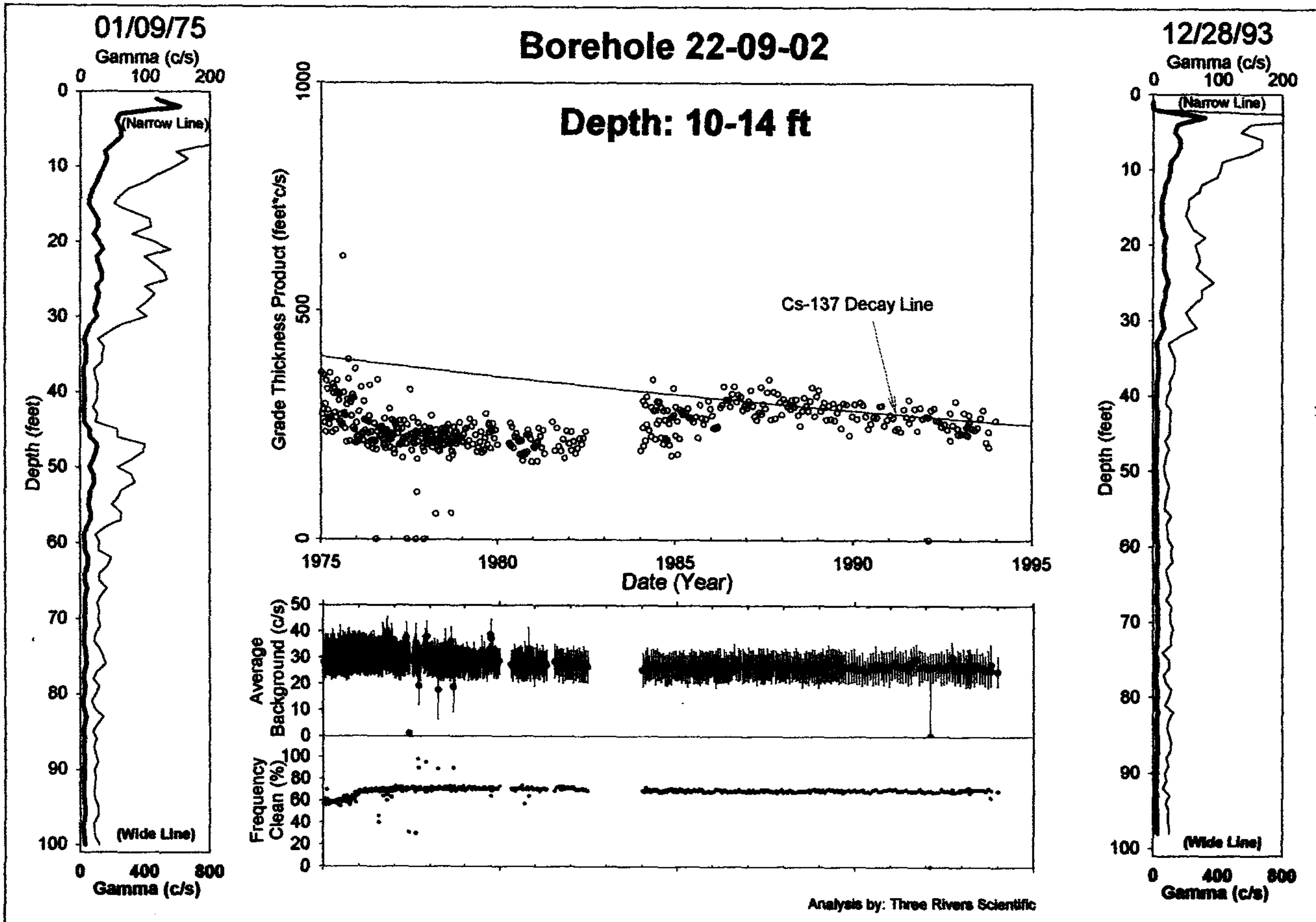
Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (5 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	12/28/1993
Number Surveys :	468

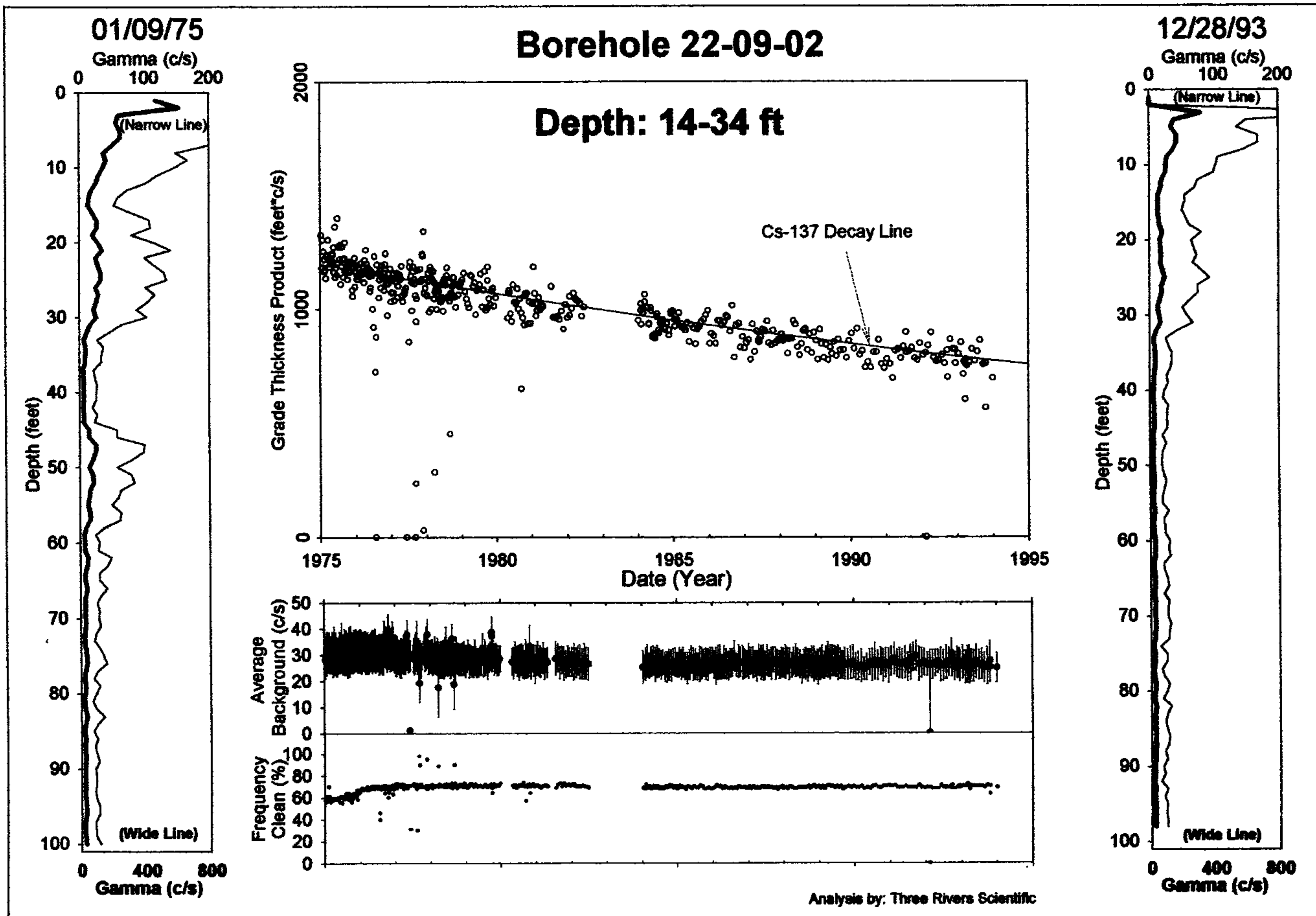
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	34 to 42 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 & 10-14 ft is TF Activity 14-34 feet is Stable 42-64 feet is Stable
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific

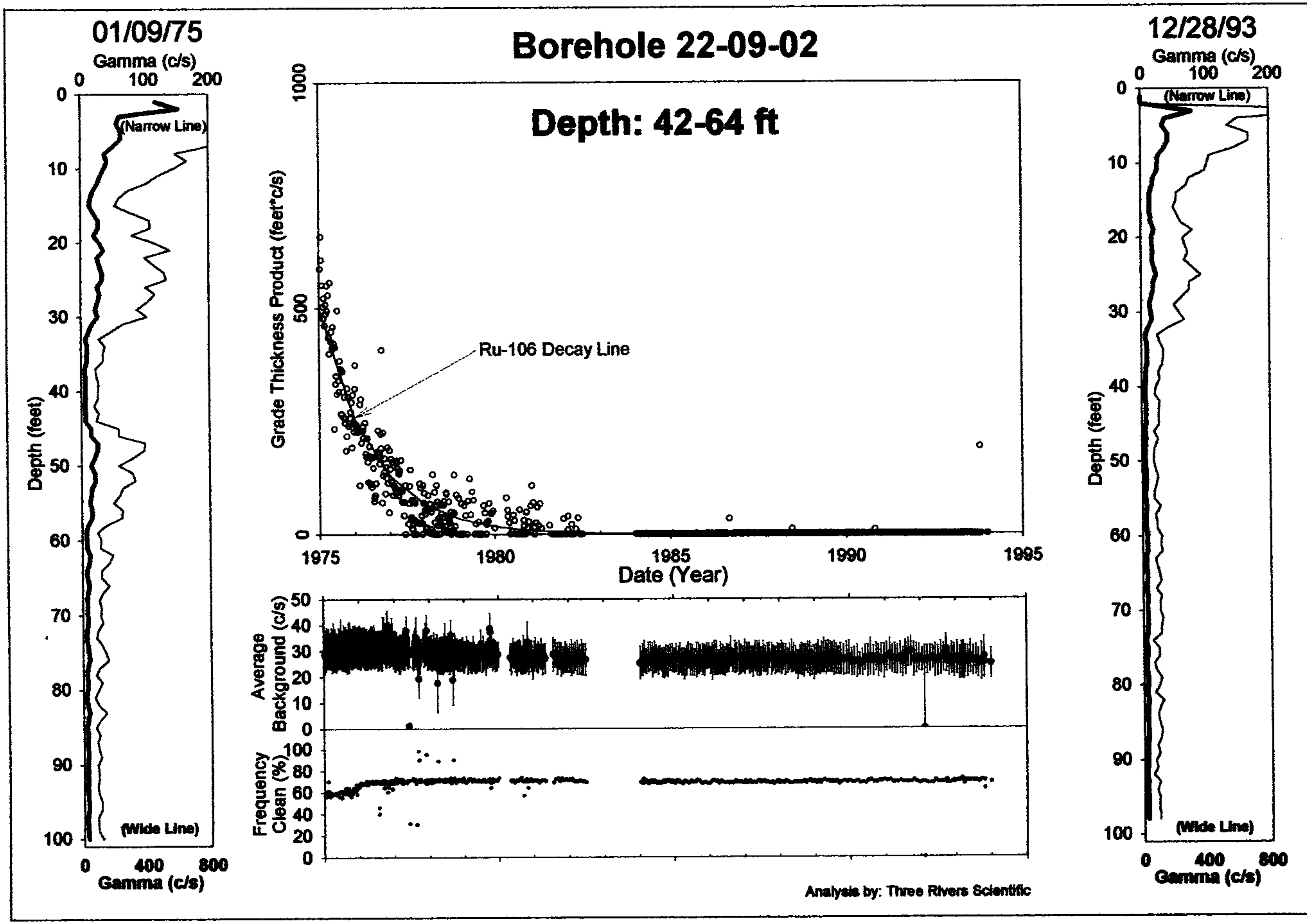

01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Borehole 22-09-02
Depth: 0-10 ft
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
12/28/93

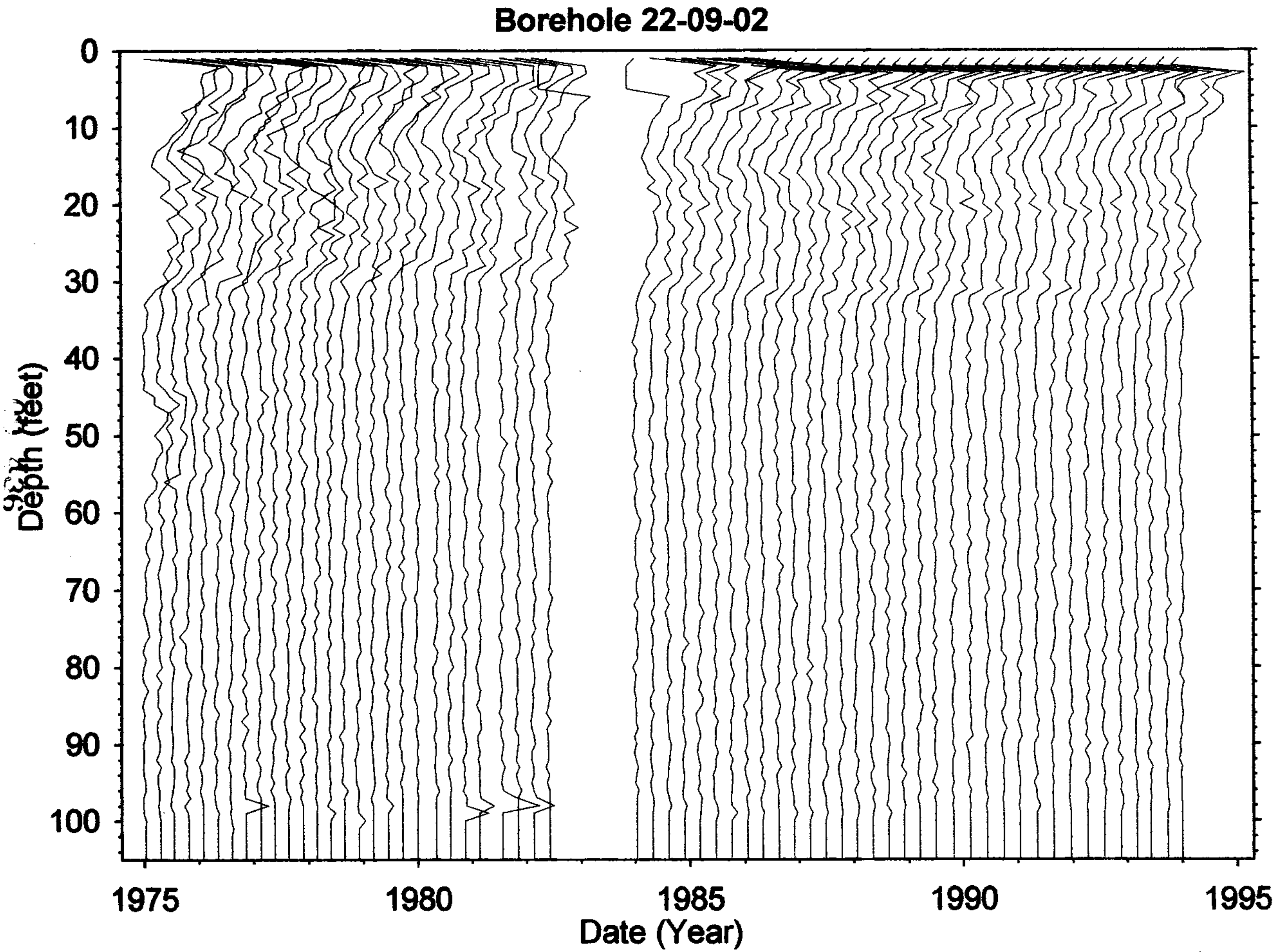

01/09/75
Gamma (c/s)
0
100
200
(Narrow Line)
Depth (feet)
(Wide Line)
0
400
800
Gamma (c/s)
Borehole 22-09-02
Depth: 10-14 ft
Grade Thickness Product (feet*c/s)
1000
500
0
Cs-137 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
12/28/93
Gamma (c/s)
(Narrow Line)
Depth (feet)
(Wide Line)
Gamma (c/s)

00 433



01/09/75
Gamma (c/s)
(Narrow Line)
Depth (feet)
(Wide Line)
Gamma (c/s)
Borehole 22-09-02
Depth: 14-34 ft
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
12/28/93
Gamma (c/s)
(Narrow Line)
Depth (feet)
(Wide Line)
Gamma (c/s)


Borehole 22-09-02
Depth: 42-64 ft
01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Grade Thickness Product (feet*c/s)
Ru-106 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
12/28/93
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
Analysis by: Three Rivers Scientific


Borehole 22-09-02
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
1975
1980
1985
1990
1995
Date (Year)

Borehole 22-09-05

Contamination (Cs-137) from 0 to 10 feet is Tank Farm Activity
Contamination (Sb-125) from 40 to 58 feet is Stable

Grade Thickness Product from 0-10 feet is erratic from 1984 to 1986, and is categorized as Tank Farm activity. Grade Thickness Product from 1976 through 1993 (except 1984 to 1986) is decreasing within counting statistics at a rate consistent with Cs-137 (identified from HPGe detector).

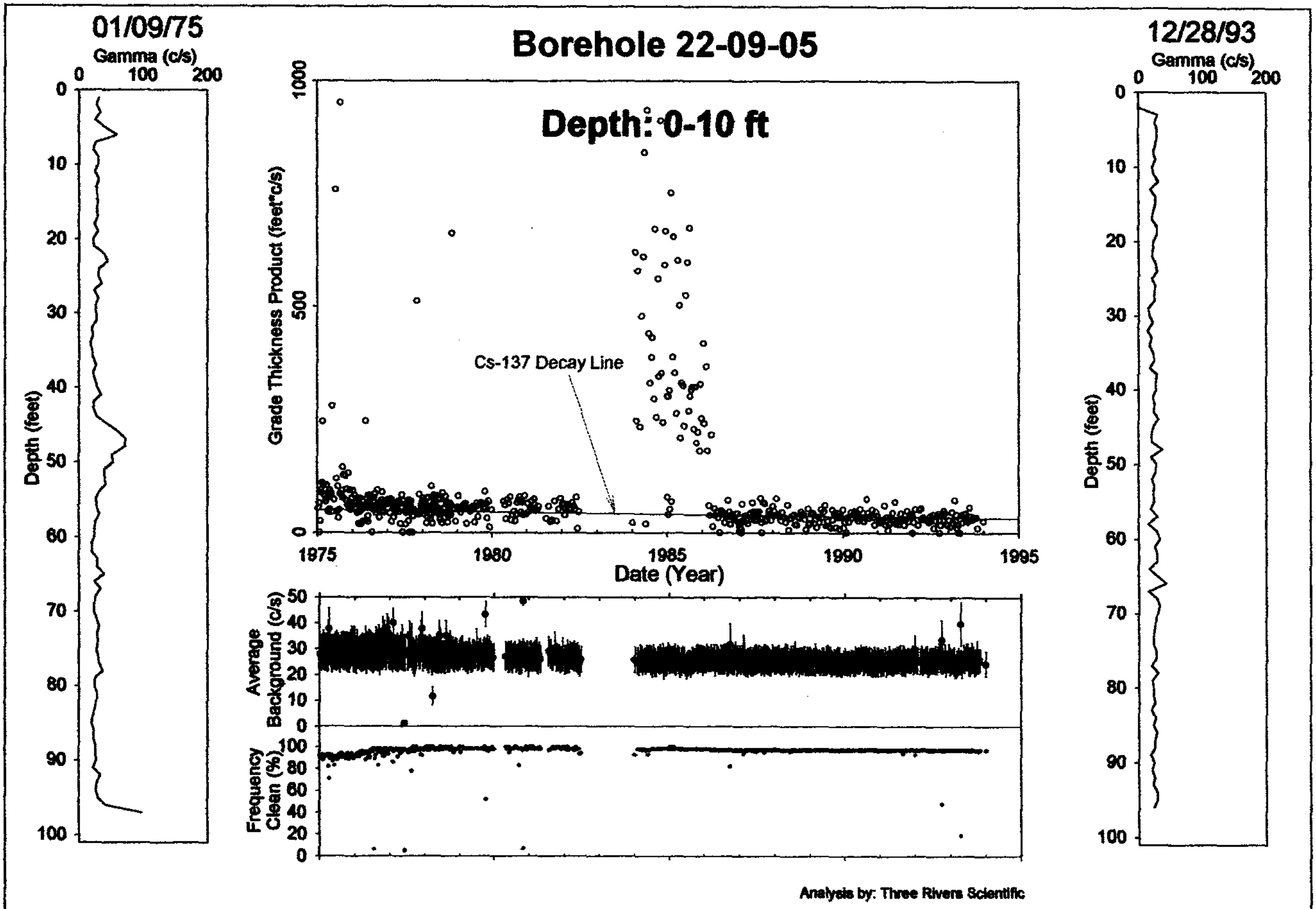
Grade Thickness Product for the radioactive zone (40-58 feet) is decreasing within the gross gamma sensitivity to each isotope and relative intensity at a rate consistent with a least squares fit of Sb-125 (hypothesis) and Cs-137 (identified from HPGe detector) between 1975 and 1993. The least squares fit results in a gross gamma contribution ratio for Sb-125 to Cs-137 of 0.1 on December 1993.

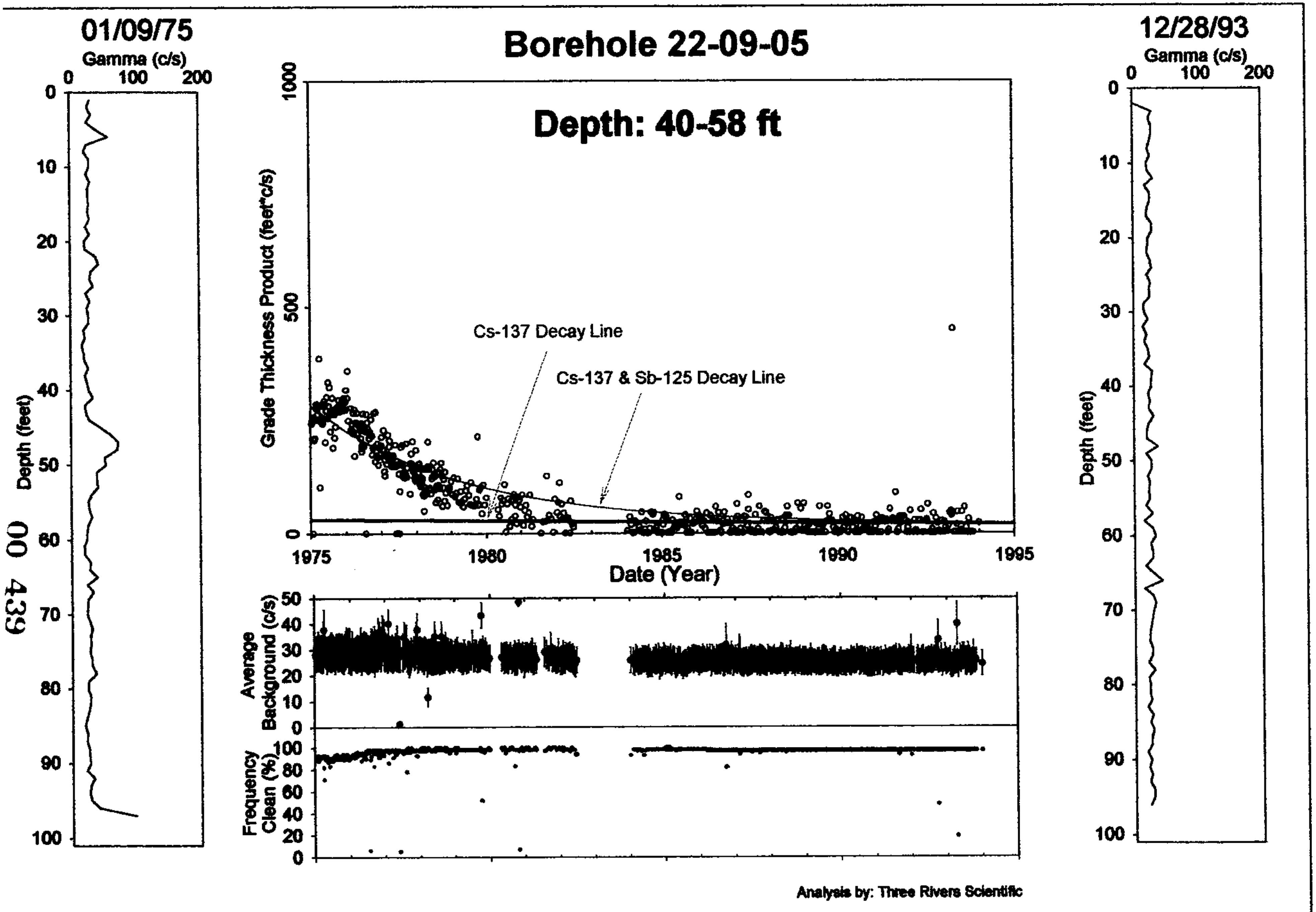
Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (5 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	12/28/1993
Number Surveys :	562

Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	12 to 38 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 feet is TF Activity 40-58 feet is Stable
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific

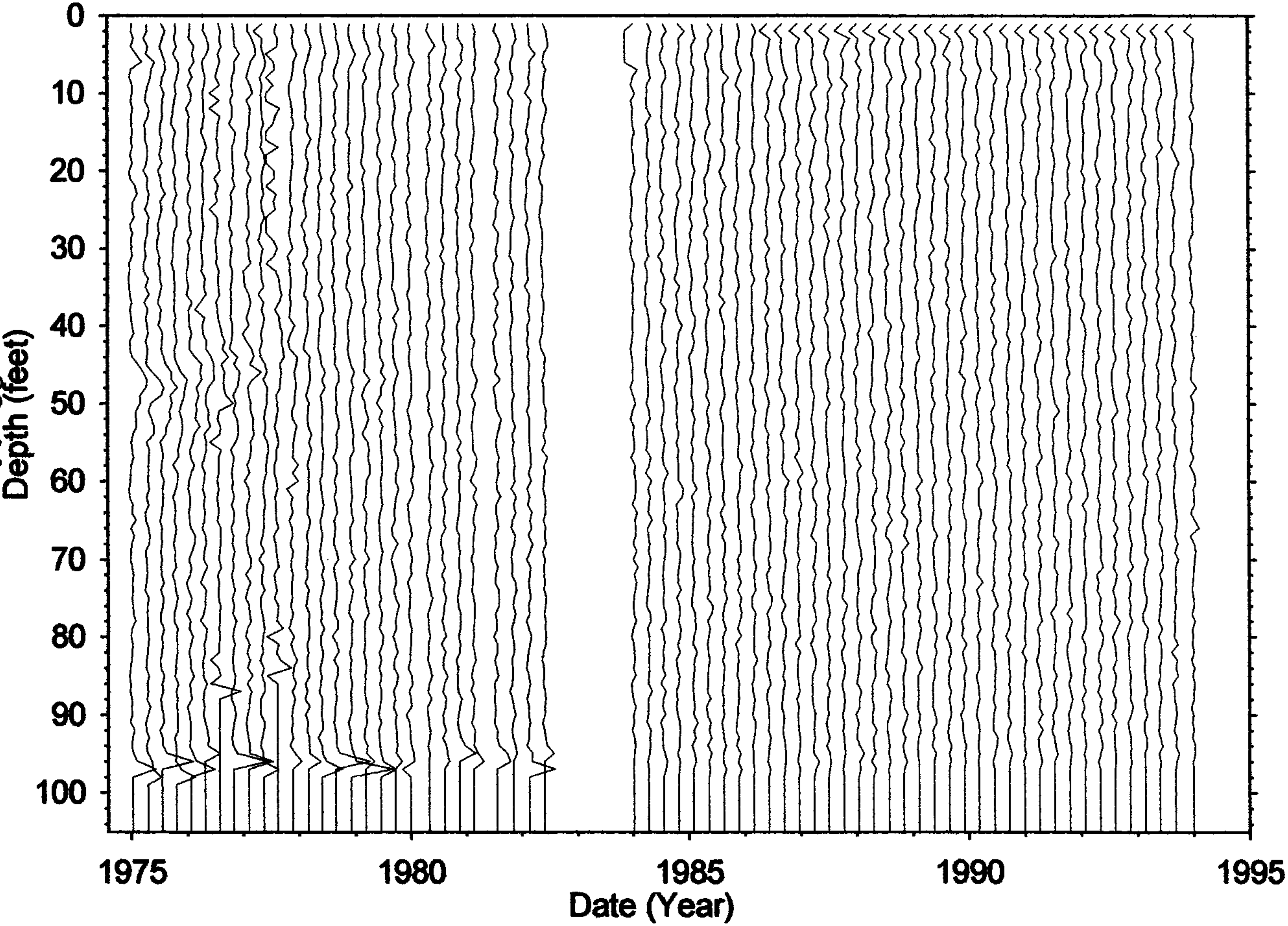

01/09/75
Gamma (c/s)
Depth (feet)
Borehole 22-09-05
Depth: 0-10 ft
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
12/28/93
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific



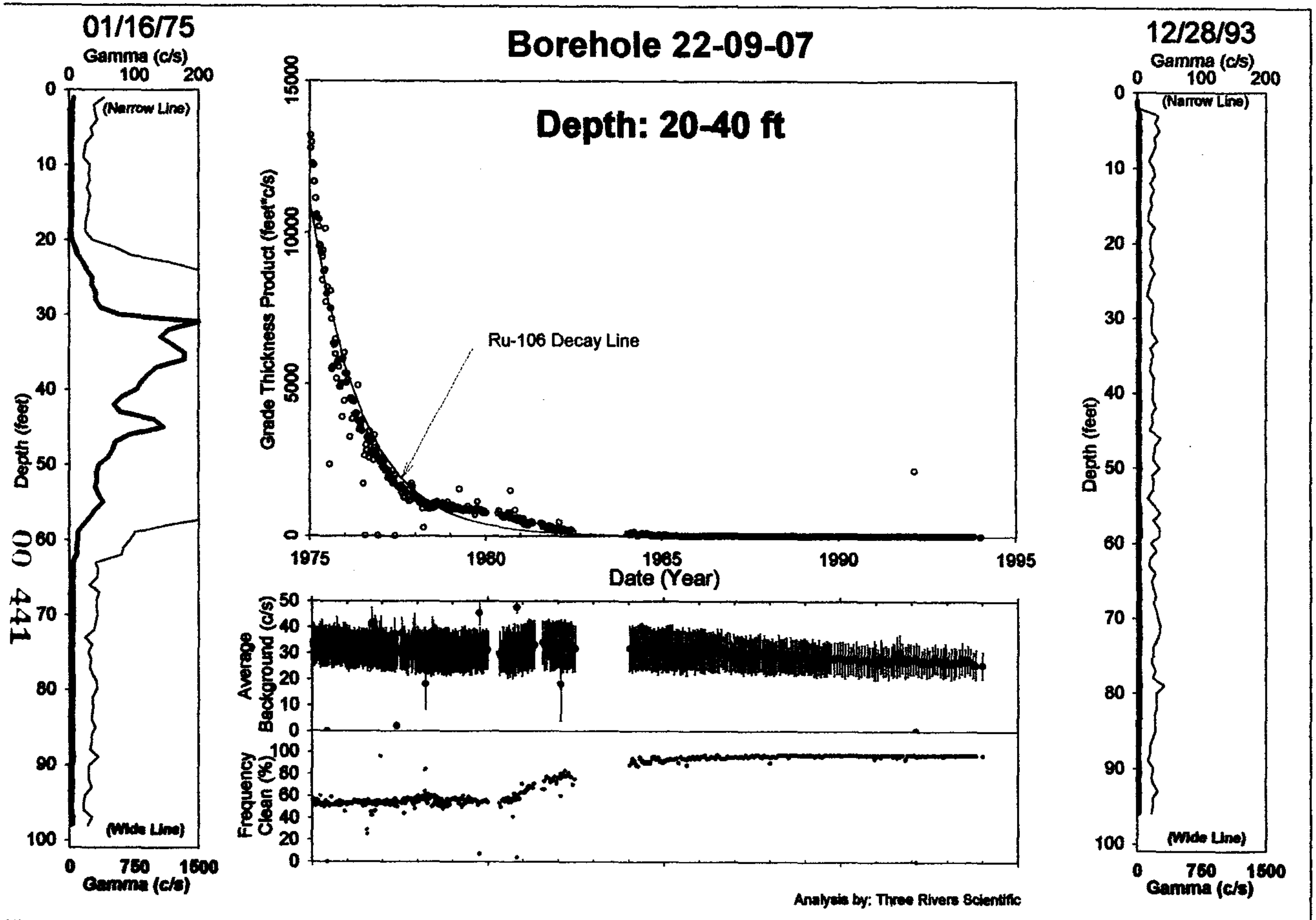
01/09/75
Gamma (c/s)
Depth (feet)
Borehole 22-09-05
Depth: 40-58 ft
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Cs-137 & Sb-125 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
12/28/93
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific

00 439

Borehole 22-09-05



HNF-3532-REV0



HNF-3532 -REV0

Borehole 22-09-07

Contamination (Ru-106) from 20 to 40 feet is **UNSTABLE**
Contamination (Ru-106) from 40 to 50 feet is **UNSTABLE** early
Contamination (Sb-125 & Ru-106) 50 to 64 feet **UNSTABLE**

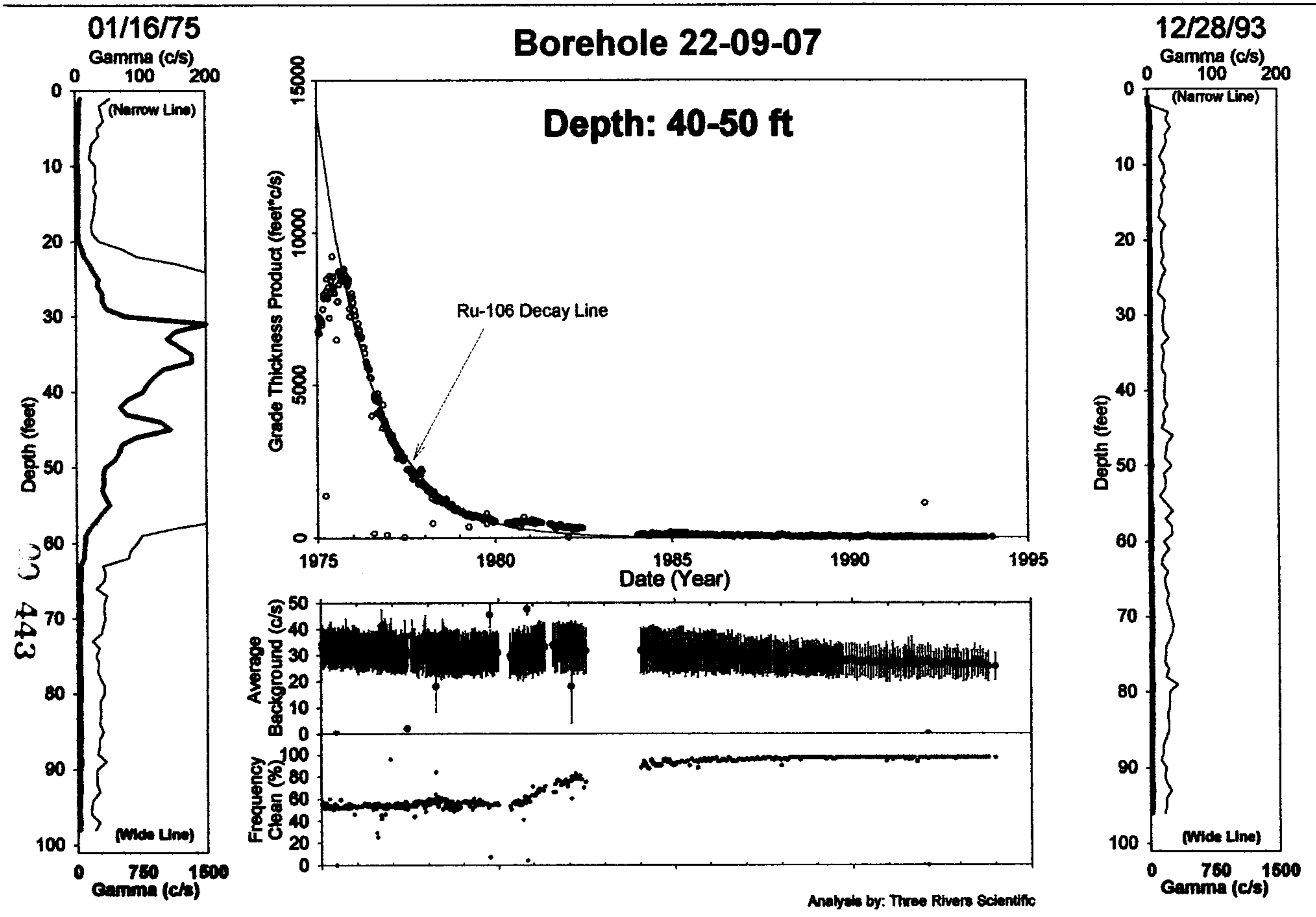
Grade Thickness Product for the radioactive zone (20-40 feet) from 1975 to 1978 is decreasing at a rate consistent with Ru-106 (hypothesis) decay, however from mid-year 1978 to 1982 the Grade Thickness Product is consistently greater than the fitted decay curve, indicating additional contaminants in this zone.
Grade Thickness Product for the radioactive zone (40-50 feet) is **Increasing** during 1975 then becomes stable and in 1976 the Grade Thickness Product is decreasing within the gross gamma sensitivity at a rate consistent Ru-106 (hypothesis) from 1976 to 1981. The Grade Thickness Product is greater than the decay curve from 1981 to 1983.
Grade Thickness Product for the radioactive zone (50-64 feet) is erratic from 1975 to 1976, then is decreasing at a rate consistent with Ru-106 and Sb-125 decay (both hypothesis) to 1980, however from 1980 to 1986 the Grade Thickness Product is consistently less than the fitted decay curve.
Grade Thickness Product for the combined radioactive zone (20-64 feet) is decreasing within the gross gamma sensitivity to each isotope and relative intensity at a rate consistent with a least squares fit of Sb-125 and Ru-106 for the 20 year surveillance period from 1975 through 1994. The least squares fit results in a gross gamma contribution ratio for Sb-125 to Ru-106 of 0.22 on January 1975.

Gross Gamma Survey Information

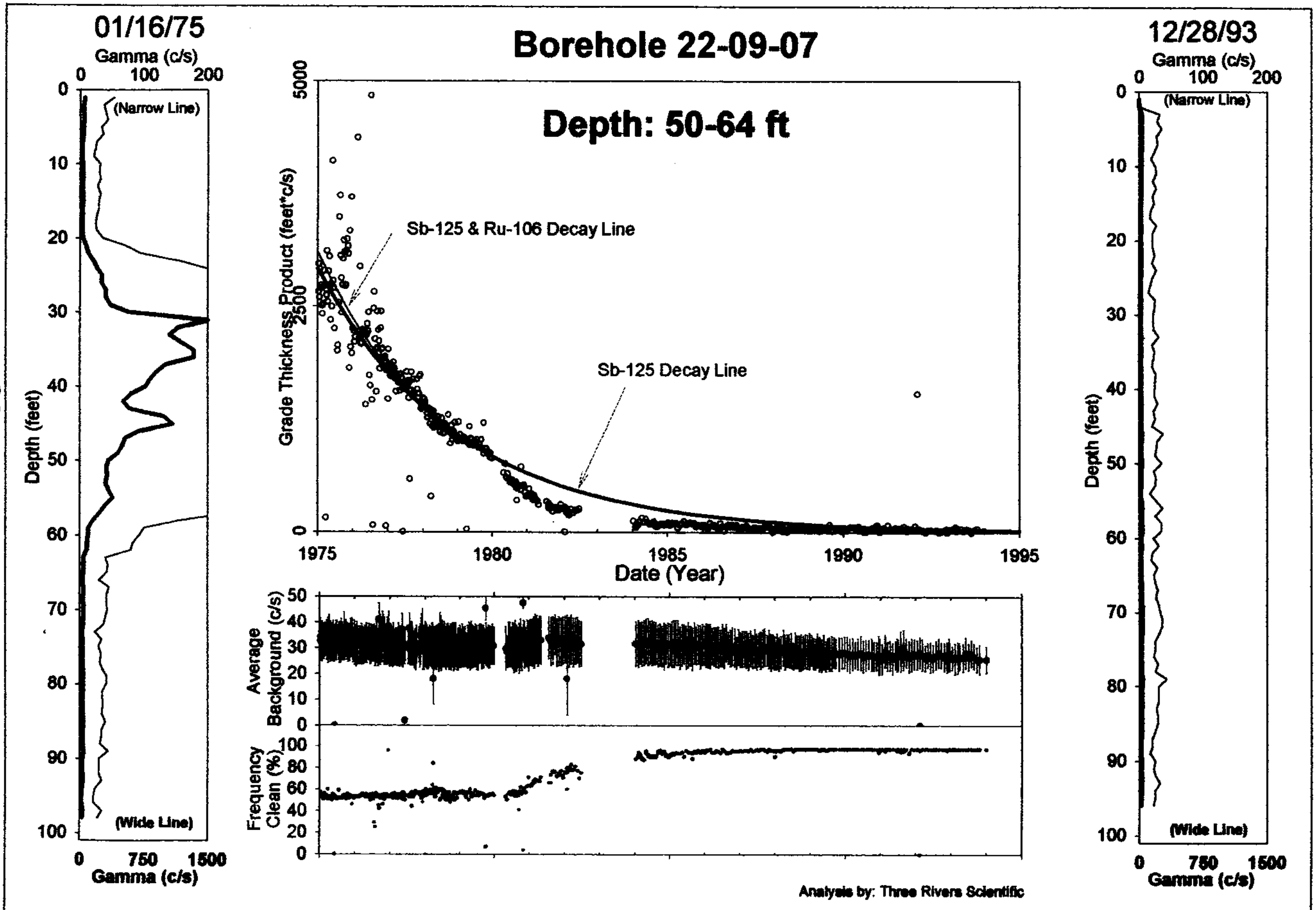
Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (5 surveys)
Borehole Depth :	97 ft
Survey Depth :	97 ft
First Survey Date :	1/10/1975
Last Survey Date :	12/28/1993
Number Surveys :	481

Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	Threshold (0< val < 50)
Depth(s) where Contamination Identified in Gross Gamma Surveys :	20-40 feet is UNSTABLE 40-50 feet is UNSTABLE 50-64 feet is UNSTABLE
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific

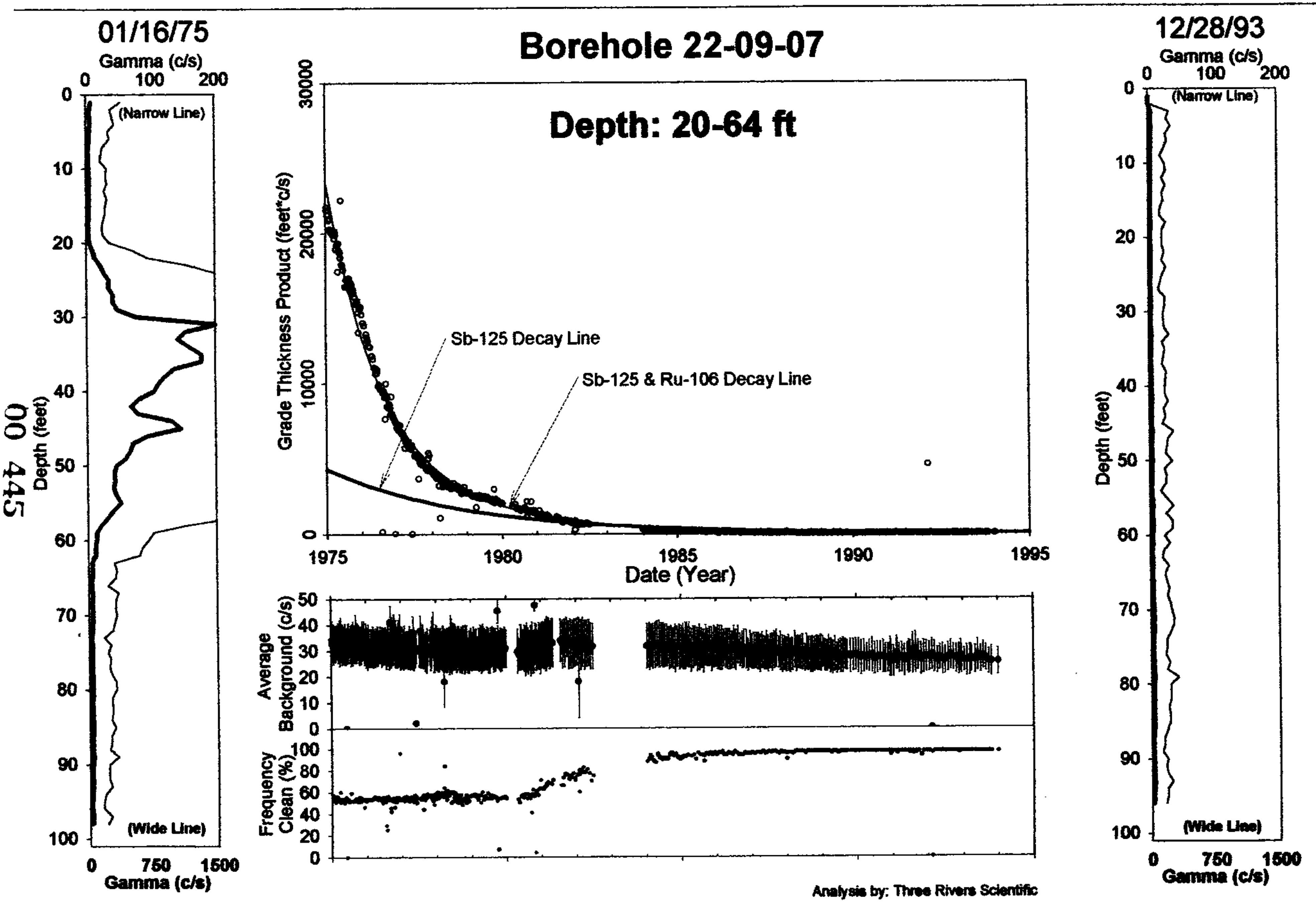


Borehole 22-09-07
Depth: 40-50 ft
01/16/75
Gamma (c/s)
0
100
200
(Narrow Line)
(Wide Line)
0
750
1500
Gamma (c/s)
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
Grade Thickness Product (feet*c/s)
0
5000
10000
15000
Ru-106 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average Background (c/s)
0
10
20
30
40
50
Frequency Clean (%)
0
20
40
60
80
100
Analysis by: Three Rivers Scientific
12/28/93
Gamma (c/s)
0
100
200
(Narrow Line)
(Wide Line)
0
750
1500
Gamma (c/s)
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
00 443



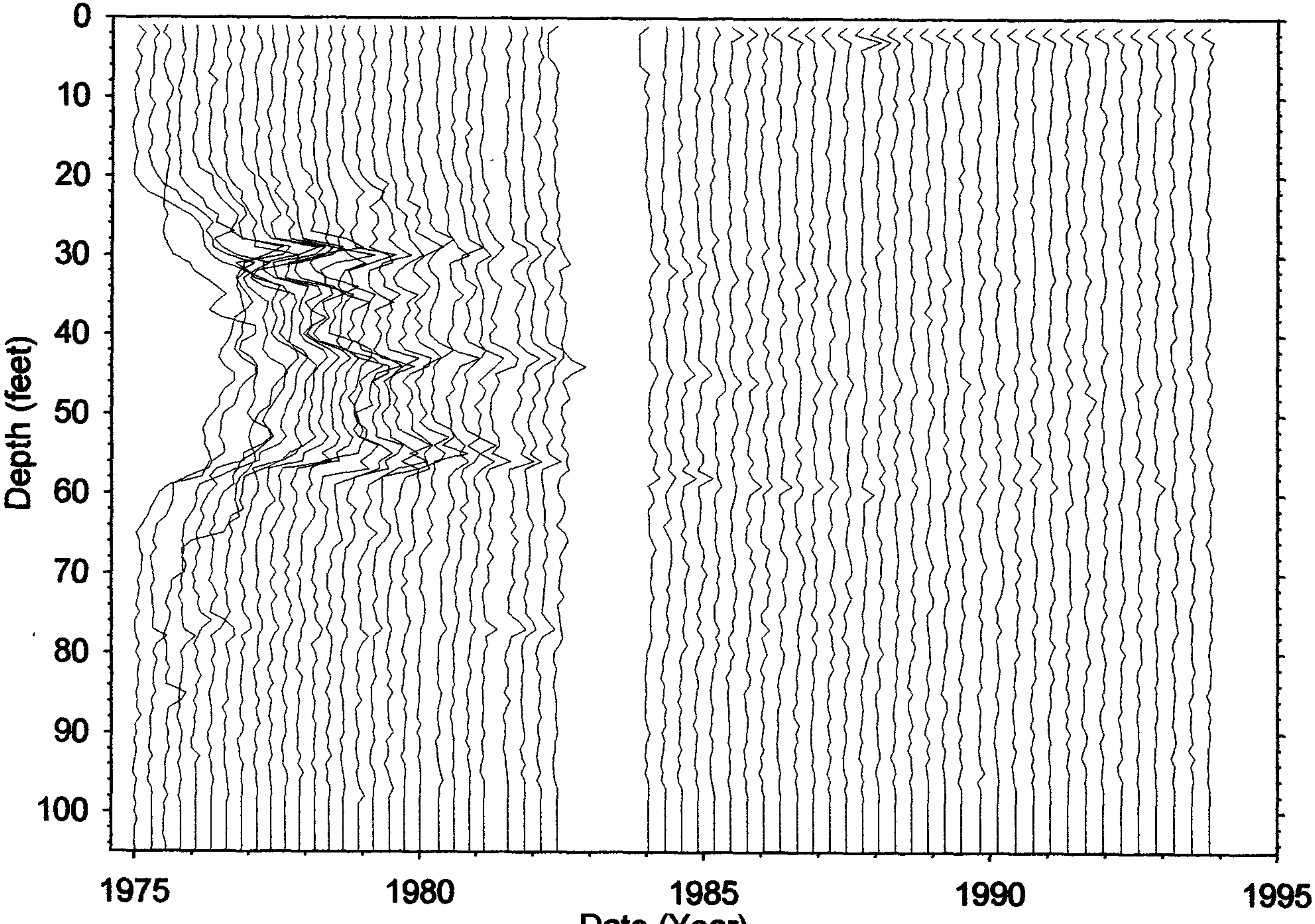
00 444

HNF-3532 -REV0


01/16/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Gamma (c/s)
Depth (feet)
Borehole 22-09-07
Depth: 20-64 ft
Grade Thickness Product (feet*c/s)
Sb-125 Decay Line
Sb-125 & Ru-106 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
12/28/93
Gamma (c/s)
(Narrow Line)
(Wide Line)
Gamma (c/s)
Depth (feet)

00 445

Borehole 22-09-07



HNF-3532 -REV0

00 446

Borehole 22-09-08

Contamination (Cs-137) from 16 to 30 feet is Undetermined
Contamination (Co-60) from 43 to 52 feet is Stable
Contamination (Co-60) from 76 to 90 feet is Undetermined

Grade Thickness Product from 16 to 30 feet does not match the decay rate of Cs-137 (identified from HPGe detector) and the gross gamma activity is at the 30,000 counts per second rate which may be beyond the linear region of the counting system.

Grade Thickness Product for the radioactive zone (43-52 feet) is decreasing within the gross gamma sensitivity at a rate consistent with Co-60 (identified by HPGe detector) from 1980 to 1993.

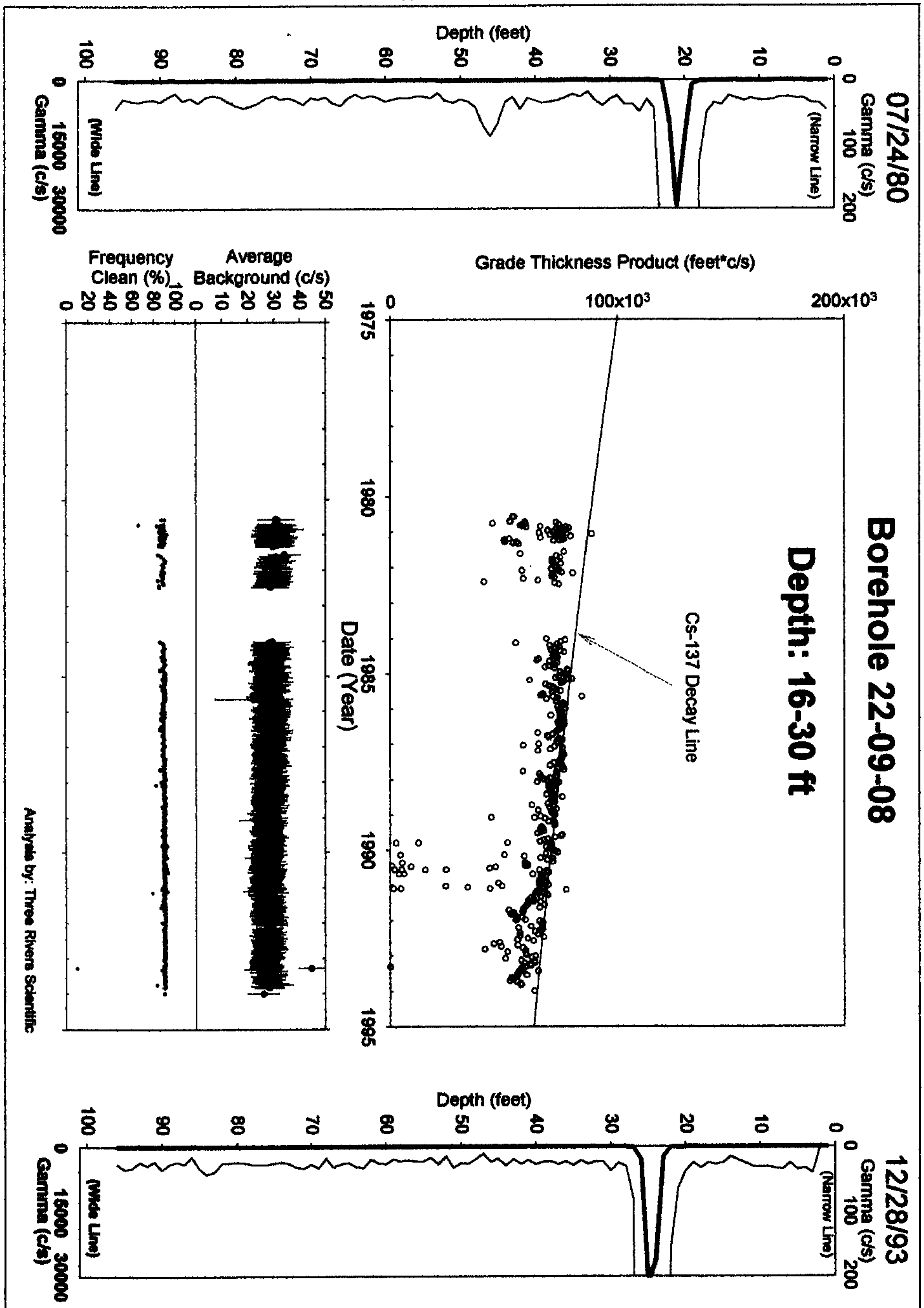
Grade Thickness Product for the radioactive zone (76-90 feet) is at low levels (detection threshold) and appears to be constant from 1984 to 1994. Stability of the zone from 1980 to 1984 can not be determined. Agreement with the decay rate of Co-60 (identified by HPGe detector) can not be determined.

Gross Gamma Survey Information

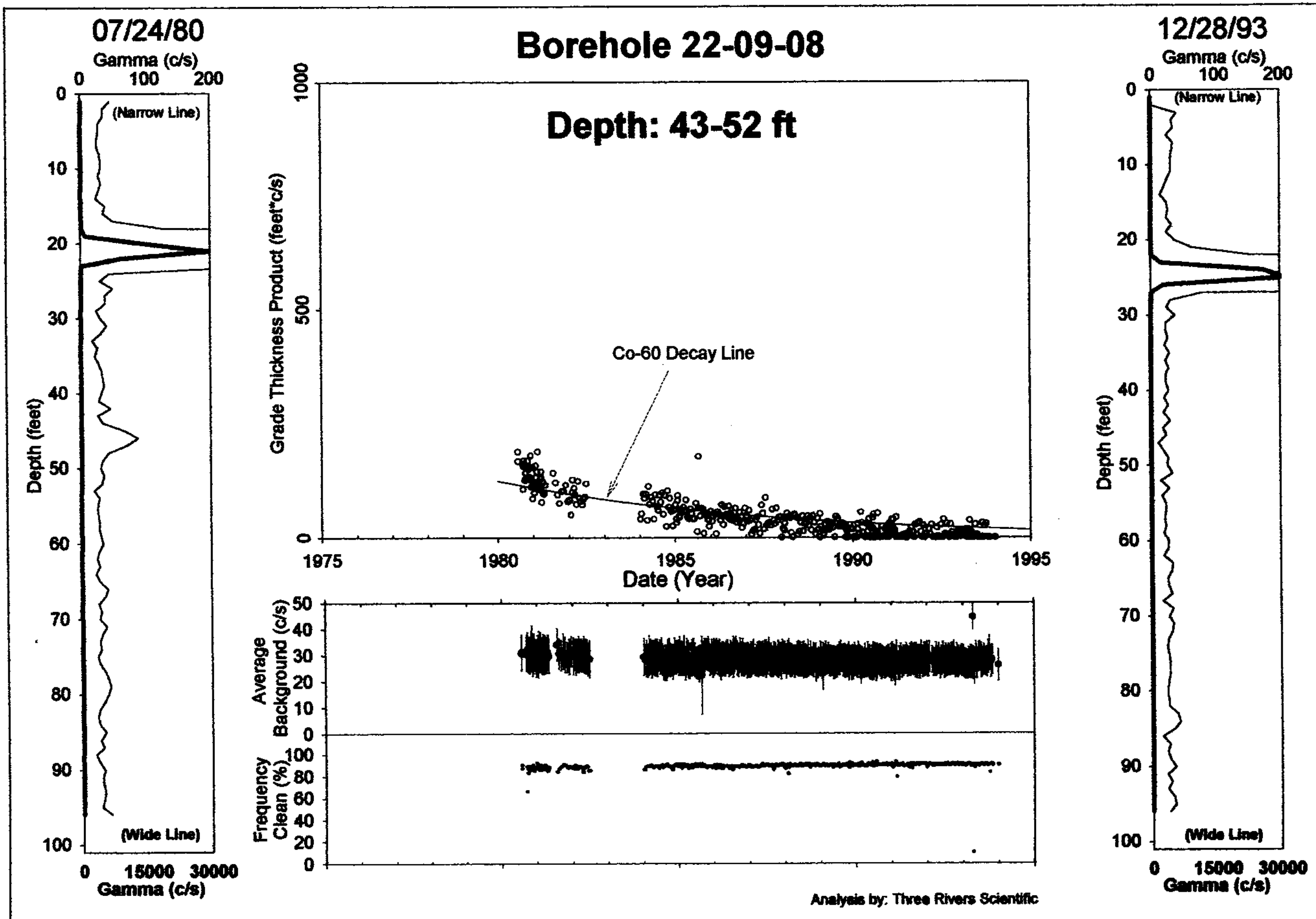
Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (4 surveys) 14: Shielded NaI (29 surveys; 1980)
Borehole Depth :	98 ft
Survey Depth :	98 ft
First Survey Date :	7/24/1980
Last Survey Date :	12/28/1993
Number Surveys :	368

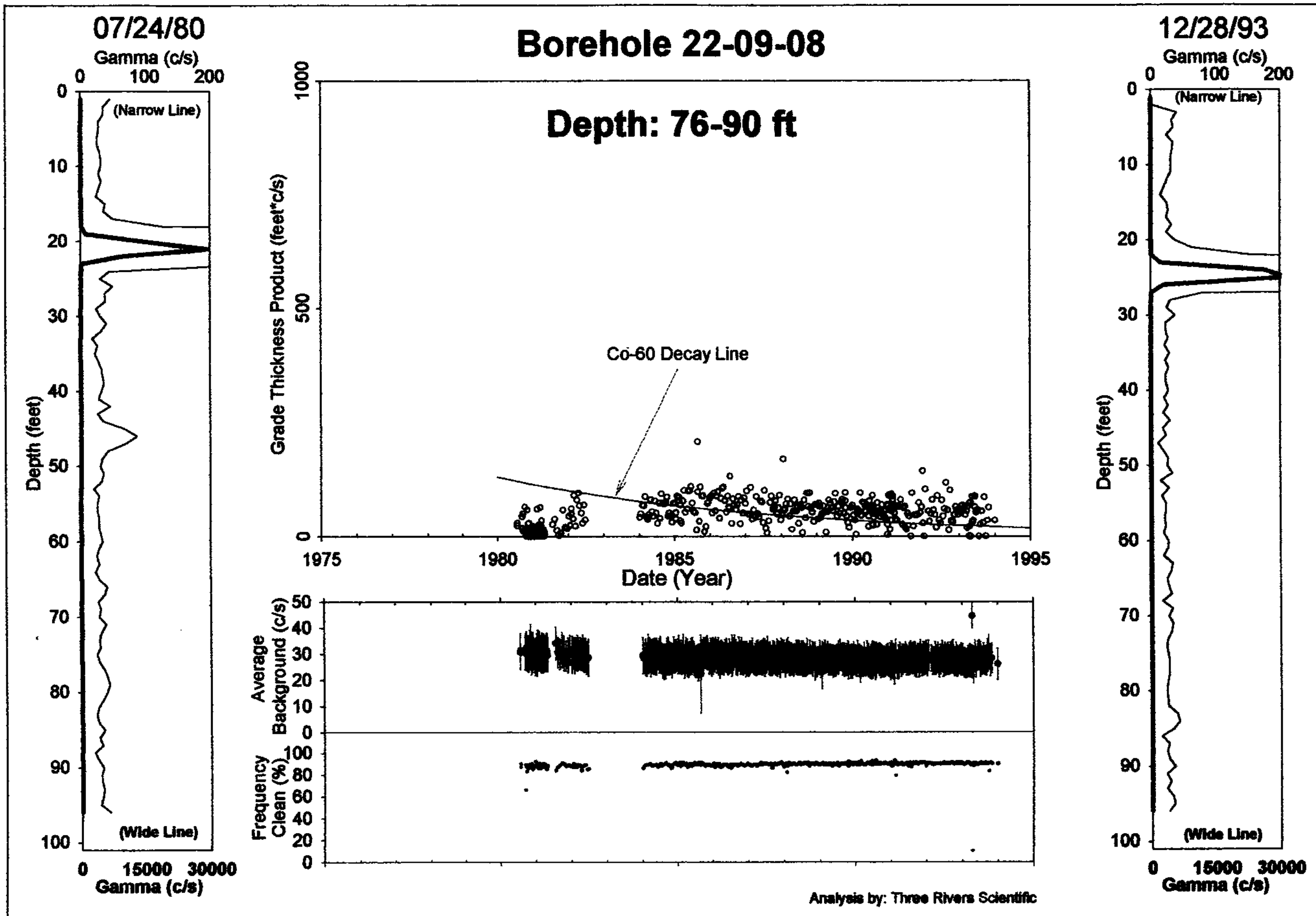
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	55 to 74 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	16-30 feet is Undetermined 43-52 feet is Stable 76-90 feet is Undetermined
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



Borehole 22-09-08
Depth: 16-30 ft
07/24/80
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
Gamma (c/s)
(Narrow Line)
0
100
200
(Wide Line)
Gamma (c/s)
0
15000
30000
Grade Thickness Product (feet*c/s)
0
100x10³
200x10³
Cs-137 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average Background (c/s)
0
10
20
30
40
50
Frequency Clean (%)
0
20
40
60
80
100
Analysis by: Three Rivers Scientific
12/28/93

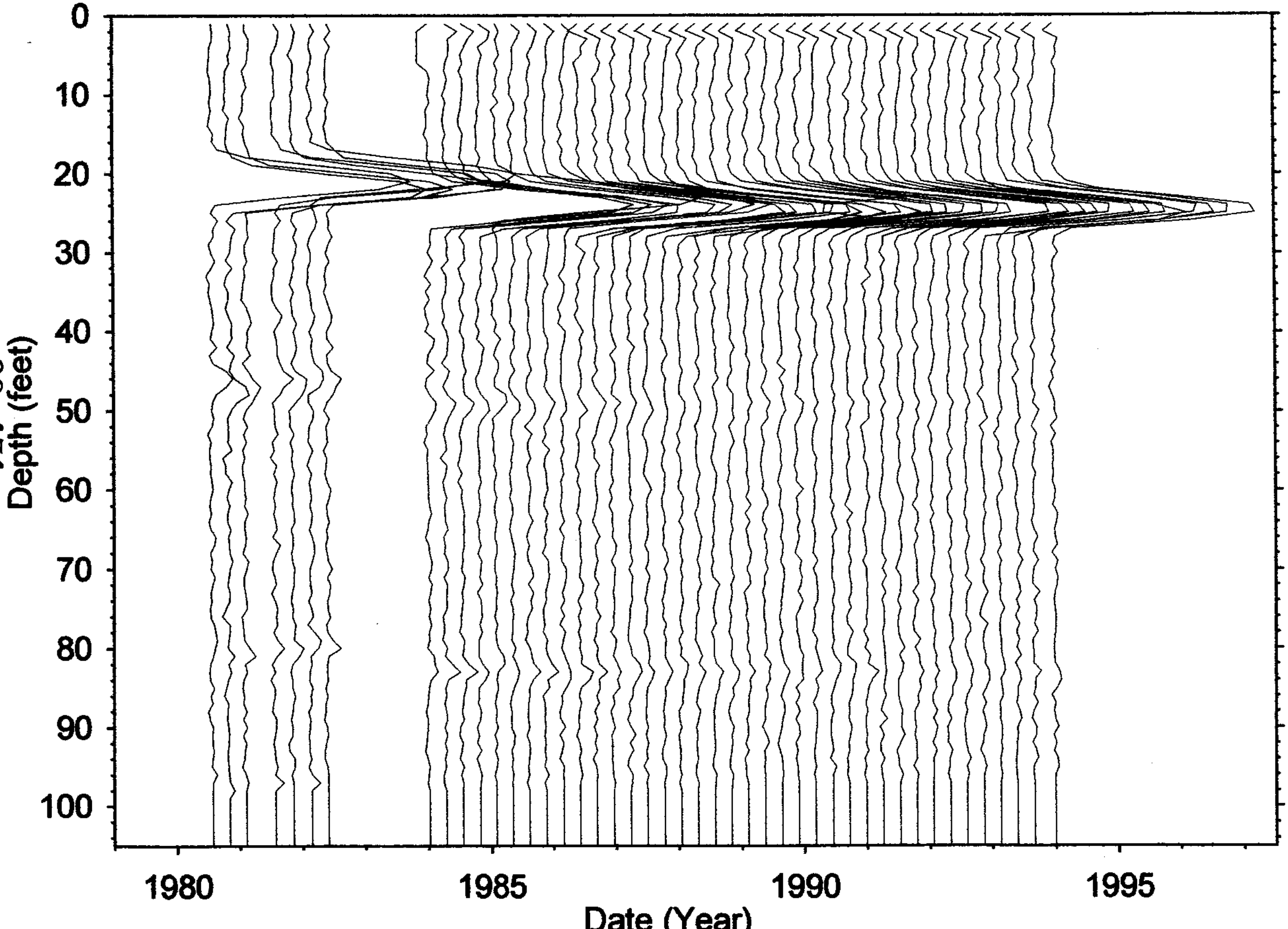

07/24/80
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
(Wide Line)
0 15000 30000
Gamma (c/s)
Borehole 22-09-08
Depth: 43-52 ft
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
1975 1980 1985 1990 1995
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
12/28/93
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
(Wide Line)
0 15000 30000
Gamma (c/s)



00 450

HNF-3532 -REV0

Borehole 22-09-08



Borehole 22-09-11

Contamination (Cs-137) from 0 to 10 feet is Tank Farm Activity
Contamination (Cs-137 & Sb-125) from 16 to 25 feet is Stable
Contamination (Ru-106) from 25 to 38 feet is Stable
Contamination (Ru-106) from 38 to 52 feet **UNSTABLE** early

Grade Thickness Product from 0 to 10 feet is erratic from 1975 through 1986, and is categorized as Tank Farm activity. Grade Thickness Product from 1986 through 1994 is decreasing within observed systematic limitations at a rate consistent with Cs-137 (HPGe detector identified).

Grade Thickness Product for the radioactive zone (16-25 feet) is decreasing within the gross gamma sensitivity to each isotope and relative intensity at a rate consistent with a least squares fit of Sb-125 (hypothesis) and Cs-137 (HPGe detector identified) between January 1975 and 1994. The least squares fit results in a gross gamma contribution ratio for Sb-125 to Cs-137 of 0.03 on December 1993.

Grade Thickness Product for the radioactive zone (25-38 feet) is decreasing within observed systematic limitations at a rate consistent with the decay of Ru-106 (hypothesis) between 1975 and 1994.

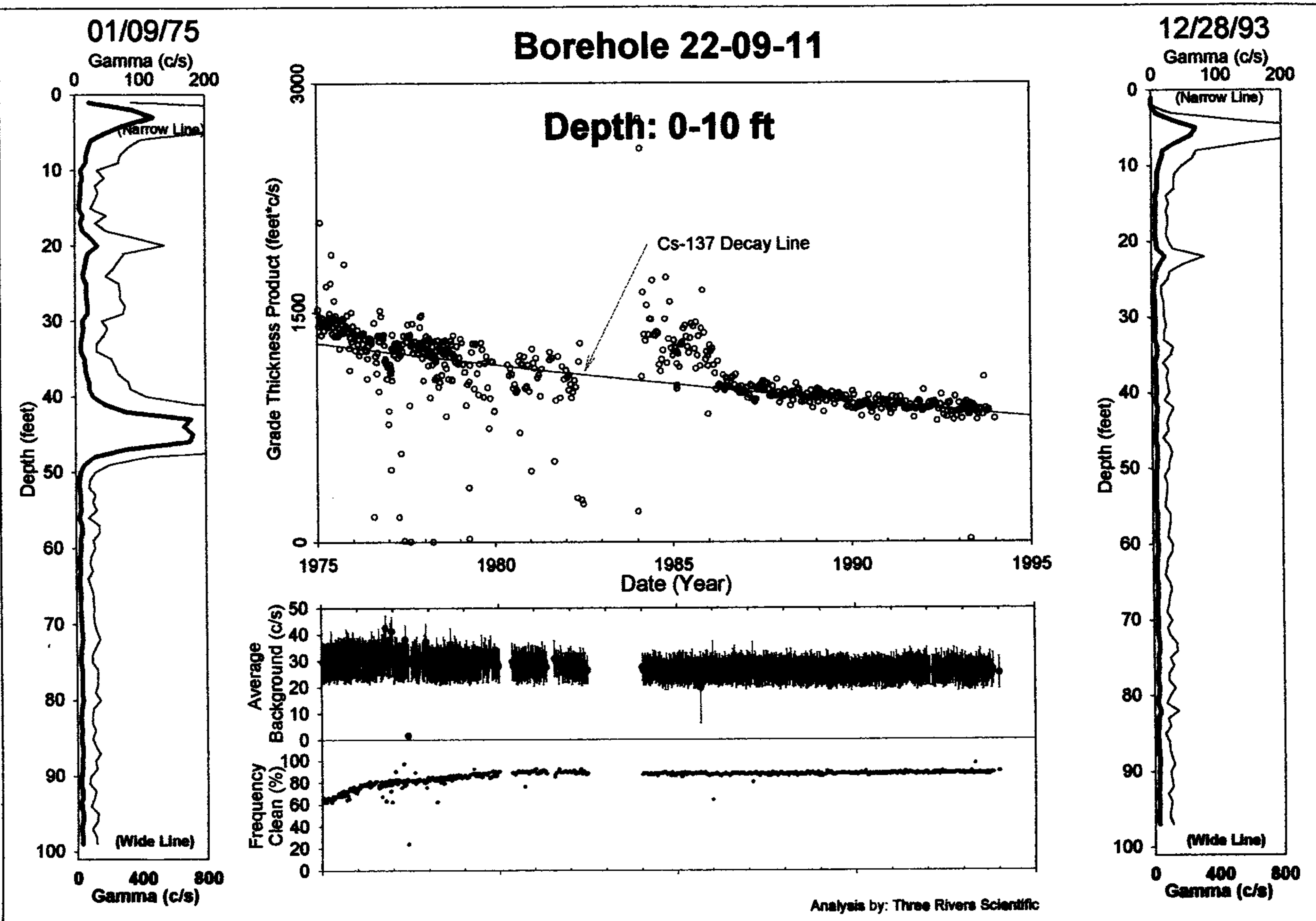
Grade Thickness Product for the radioactive zone (38-52 feet) is decreasing at a rate that exceeds the decay of Ru-106 (hypothesis) in 1975 then from 1976 to 1993 the rate of decrease is consistent with the decay of Ru-106.

Gross Gamma Survey Information

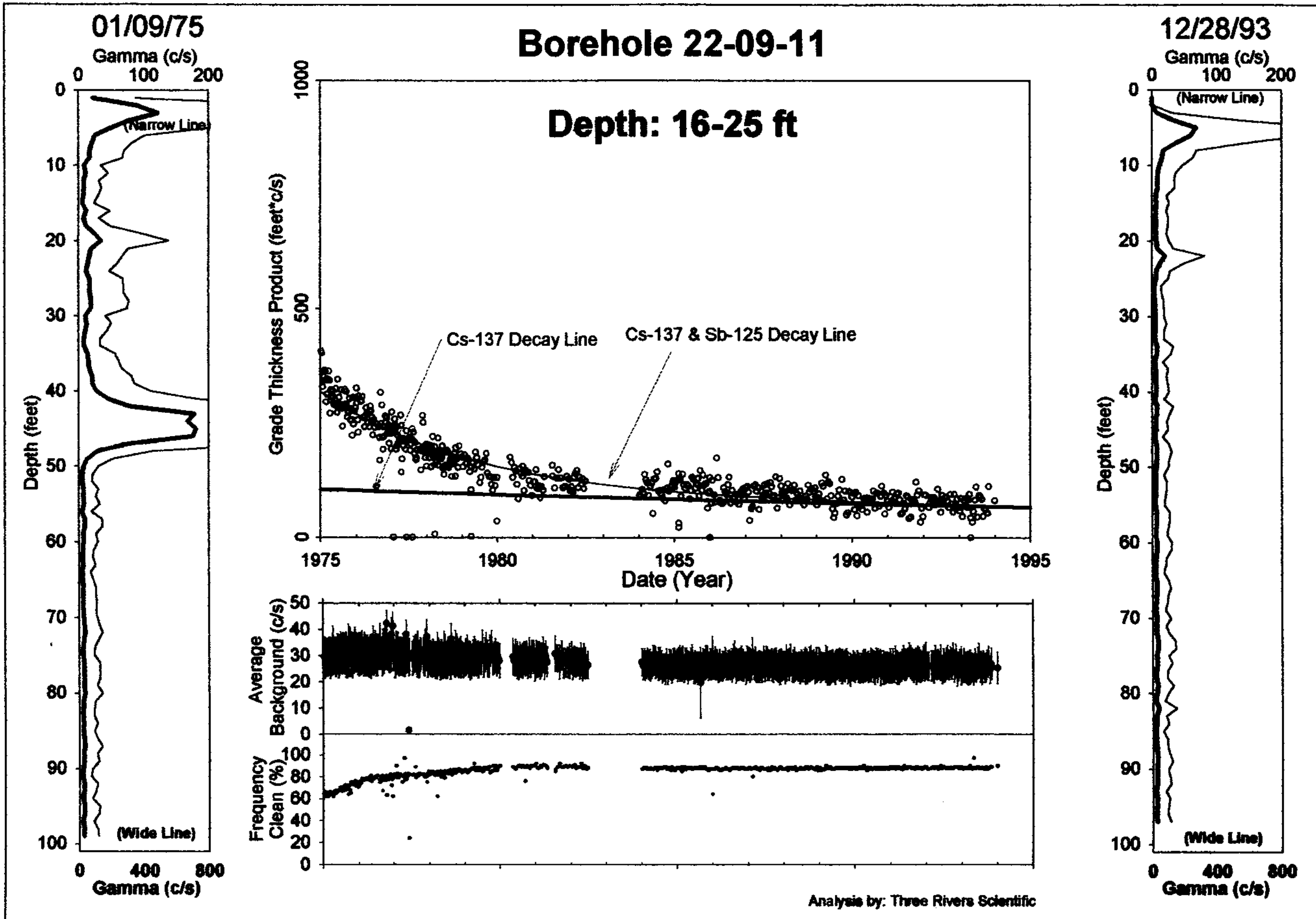
Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (5 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	12/29/1993
Number Surveys :	552

Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	60 to 90 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 feet is TF Activity 16-25 feet is Stable 25-38 feet is Stable 38-52 feet was UNSTABLE early
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific

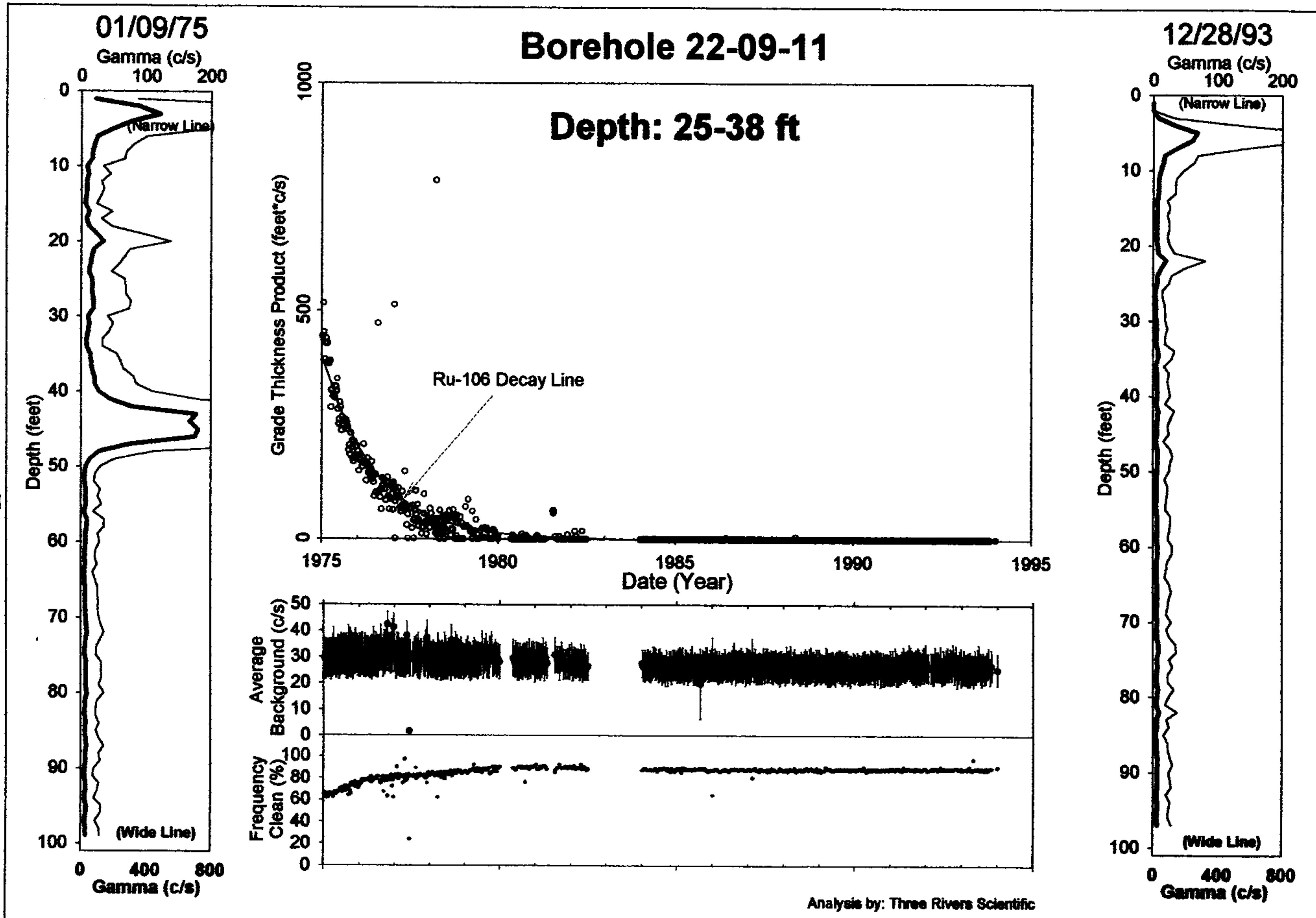


01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Borehole 22-09-11
Depth: 0-10 ft
Cs-137 Decay Line
Grade Thickness Product (feet*c/s)
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
12/28/93

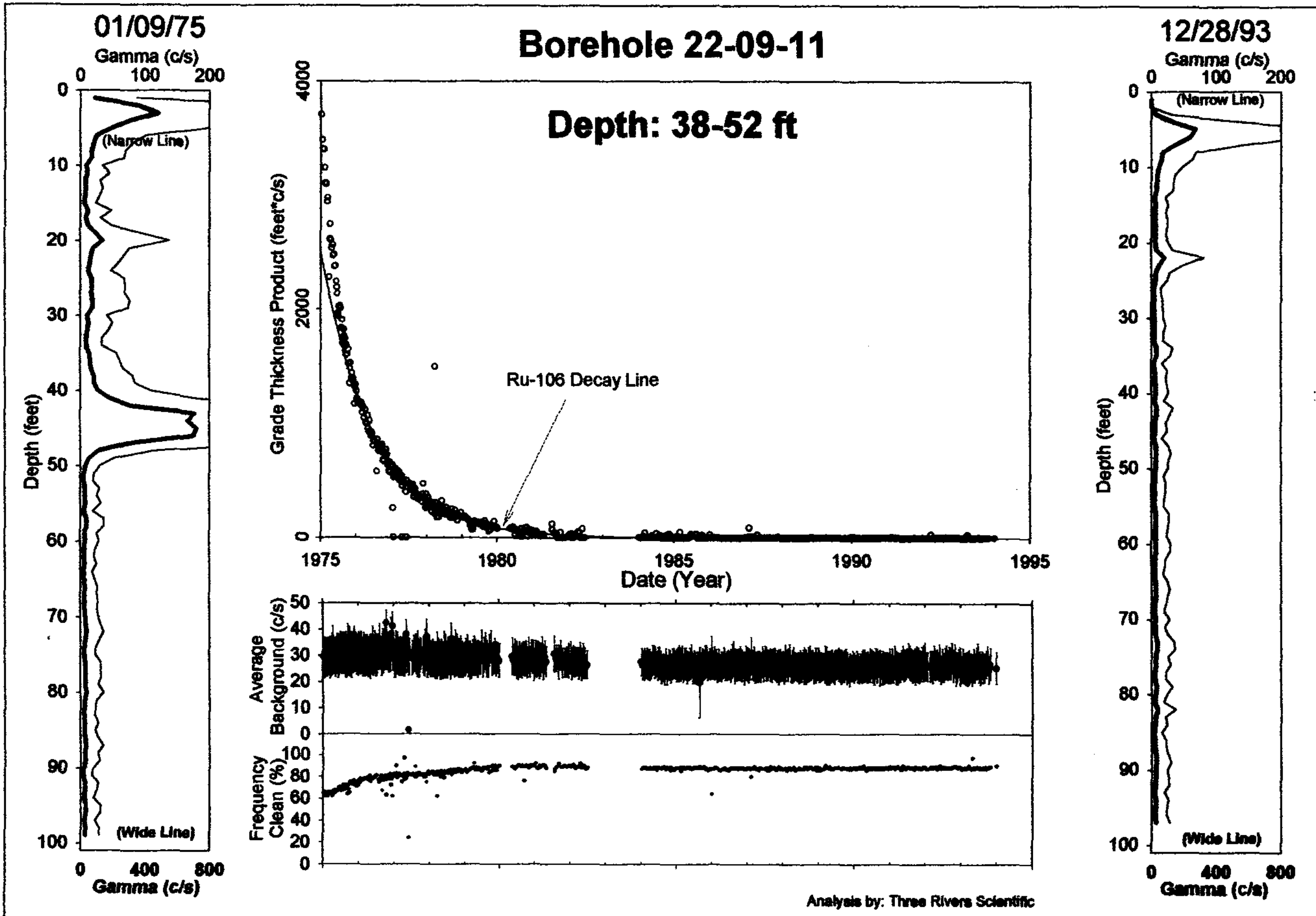


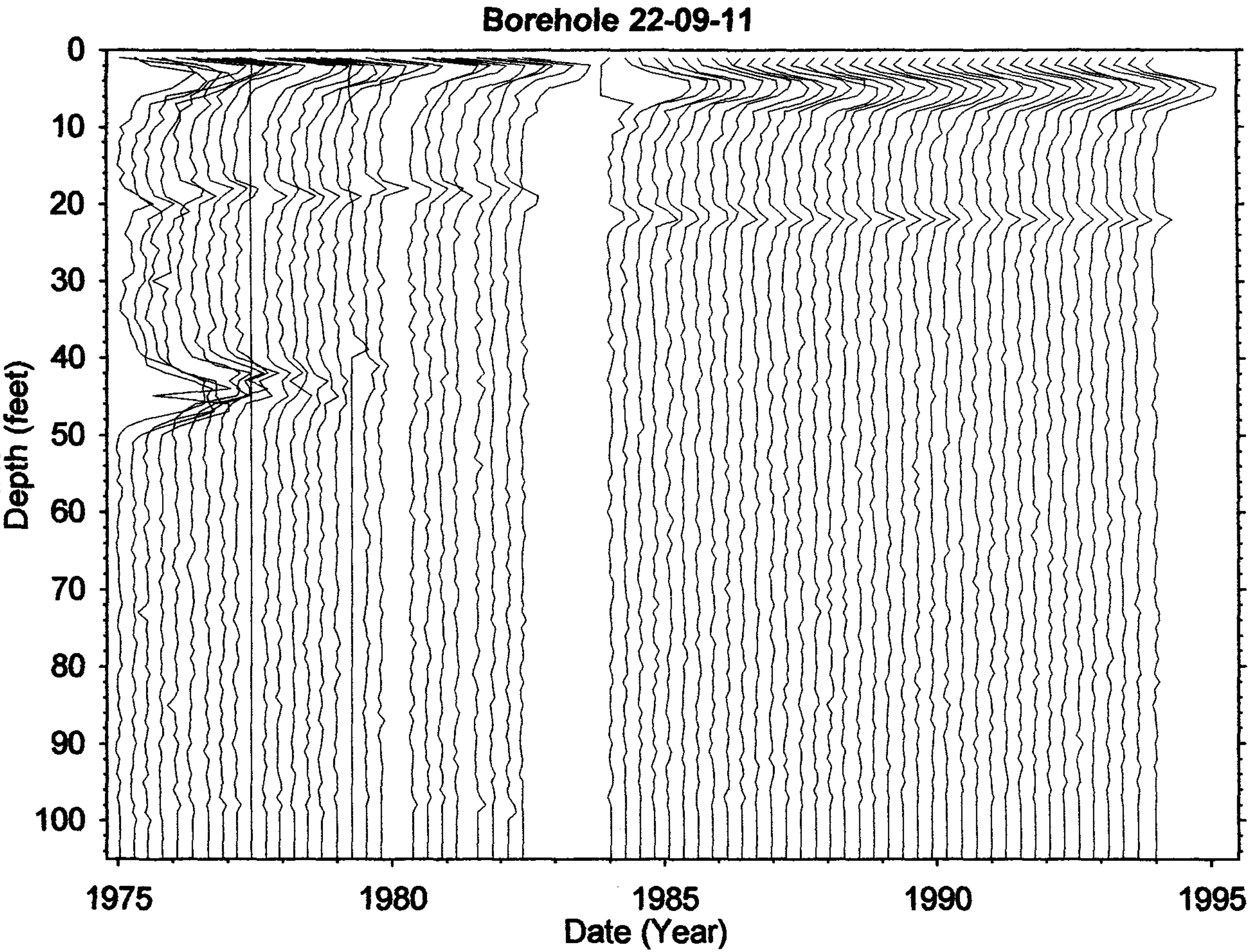
01/09/75
Gamma (c/s)
0 100 200
(Narrow Line)
(Wide Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
0 400 800
Gamma (c/s)
Borehole 22-09-11
Depth: 16-25 ft
Grade Thickness Product (feet*c/s)
0 500 1000
Cs-137 Decay Line
Cs-137 & Sb-125 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
12/28/93
Gamma (c/s)
0 100 200
(Narrow Line)
(Wide Line)
Depth (feet)
0 400 800
Gamma (c/s)

00 454



Borehole 22-09-11
Depth: 25-38 ft
01/09/75
Gamma (c/s)
(Narrow Line)
(Wide Line)
Depth (feet)
Gamma (c/s)
12/28/93
Grade Thickness Product (feet*c/s)
Ru-106 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific


01/09/75
Gamma (c/s)
0
100
200
(Narrow Line)
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
(Wide Line)
0
400
800
Gamma (c/s)
Borehole 22-09-11
Depth: 38-52 ft
Grade Thickness Product (feet*c/s)
4000
2000
0
Ru-106 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average Background (c/s)
50
40
30
20
10
0
Frequency Clean (%)
100
80
60
40
20
0
Analysis by: Three Rivers Scientific
12/28/93
Gamma (c/s)
0
100
200
(Narrow Line)
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
(Wide Line)
0
400
800
Gamma (c/s)



HNF-3532 -REV0

Dry Well Survey Analysis - Notes

Borehole 34 (22-09-01) Total # Surveys 682 Probe Type 04
\# neutron surveys 6 # GR Surveys 674
Log Date: 75-01-09 1st 93-12-28 Last Presentation Plot Dates
(If different from 1st & Last)
Isotope from Spectral Survey: Cs < .8 pCi/g / Co & Cs < .7 pCi/g Both Max Survey Depth 100
Contamination Zone Depth(s): 24-35 / 40-55 FT

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-07-01	85	90	
77-06-02	83	95	
76-07-28	16	98	
80-09-17	19	90	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
78-03-22	NOISY	100	
82-02-02	BAD SURVEY	40	
91-02-16	HI-BKG	100	
92-09-22	BAD SURVEY	100	
93-04-13	TOOL FAIL	100	
93-09-16	BAD SURVEY	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
76-07-01	% CLEAN	91	5%	1.2	
76-09-03	AVG BKG	97	68%	33.4	
76-12-16	AVG BKG	95	73%	40.8	
77-02-04	% CLEAN	95	57%	44.6	
77-06-02	% CLEAN	95	11%	1.3	
78-07-12	AVG BKG	95	96%	14.6	
93-04-13	% CLEAN	96	38%	30.6	

Analysis Notes

num surveys rejected: (0) ZERO Background = (0<~~val~~<50) 10-20
24-35' ZONE HAS SHORT LIVED RAD (FITS RU-106 W/IN STATS)
40-55 FT ZONE CAN BE FIT (ALMOST W/IN STATS) TO ~~Sb~~ & RU DECAY
SINCE 1985 - RAD (40-55') IS < DETECT. FOR TF-NAI SURVEY
Co-60 < 0.7 pCi/g @ 1997 NOT REQUIRED FOR FIT OF TF DATA
Category: (Stable, TF Activity, Undetermined, CHANGED BOTH ZONES (24-35 & 40-55')

Analyst Name Randall Price S/W ver (TFGROSS) V2.20.

filein := "two40-55.txt" **Well 22-09-01** 2-COMPONENT FIT

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

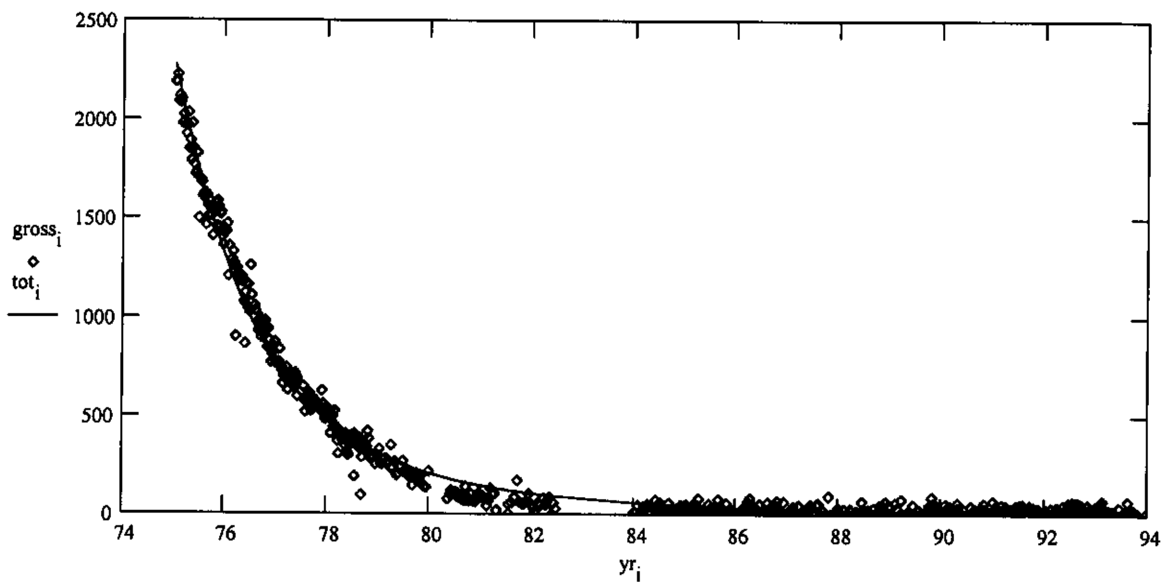
N := last(yr)   N = 659   i := 0..N   k := 0..300   j := 0..299

1st Isotope is Sb-125 ~~Co (5.27 yrs)~~)   τco := 2.77   aco := 510

2nd Isotope is Ru-106 (1.02 yrs) τ2 := 1.020   a2 := 1800

$Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := a2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$gross_i := net_i$ This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}} \right]\right]^2$$

Given

ssq(aco, a2) = 0   1 = 1

$$\begin{bmatrix} \alpha co \\ \alpha 2 \end{bmatrix} := Minerr(aco, a2)$$

Sb-125 αco = 514.041   Ru-106 $\alpha 2 = 1.8 \cdot 10^3$

Sb/Ru $\frac{\alpha co}{\alpha 2} = 0.286$

$Co_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := \alpha 2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop.txt") := out   Ratio ~~Co/U~~ Sb/Ru $\frac{Co_N}{X2_N} = 994.027$

filein := "GTP40-55.txt" **Well 22-09-01** 3-COMPONENT FIT

A := READPRN(filein)

$yr := A^{\langle 1 \rangle}$ $net := A^{\langle 7 \rangle}$ $bkg := A^{\langle 6 \rangle}$ $max := A^{\langle 4 \rangle}$

N := last(yr) N = 655 i := 0..N k := 0..300 j := 0..299

$\tau cs := 2.77$ $\tau co := 5.27$ $\tau eu := 1$

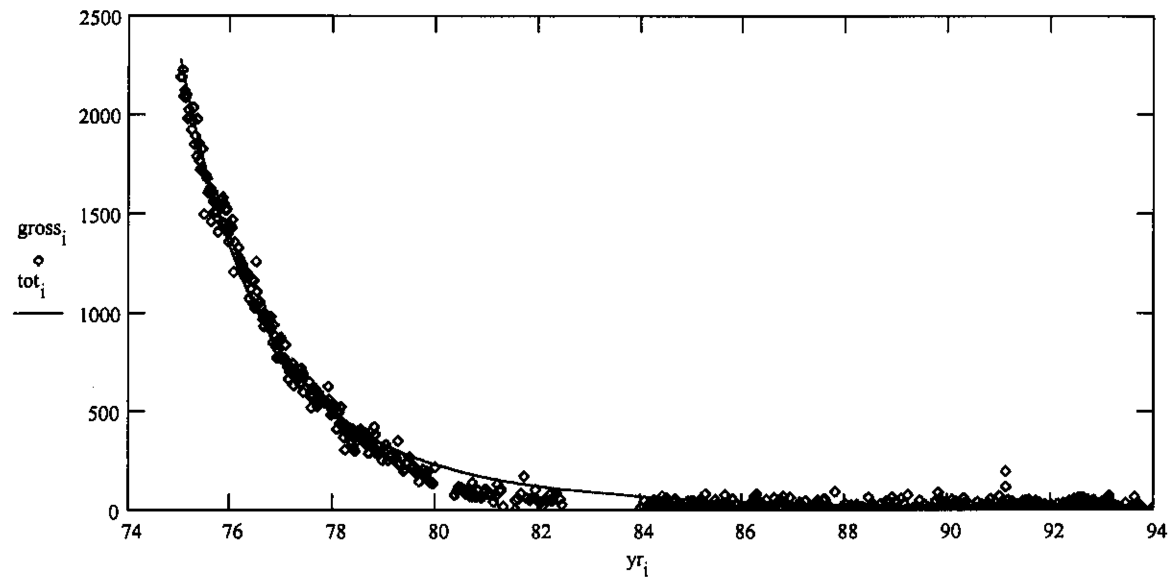
$acs := 600$ $aco := 10$ $aeu := 1700$

Eu variables are Ru-106
Cs variables are Sb

$$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \qquad Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \qquad Eu_i := aeu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \cdot 1 \qquad tot_i := Cs_i + Eu_i + Co_i$$

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1, a3, a2) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + \left[a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} + a2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \right]\right]\right]^2$$

Given

ssq(acs, aeu, aco) = 0 1 = 1 2 = 2

$$\begin{bmatrix} \alpha cs \\ \alpha eu \\ \alpha co \end{bmatrix} := \text{Minerr}(acs, aeu, aco)$$

Co-60 NOT REQ'D FOR FIT

$\alpha cs = 621.888$	$\alpha eu = 1.733 \cdot 10^3$	$\alpha co = -39.742$
Sb-125	Ru-106	Co-60

$$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \qquad Eu_i := \alpha eu \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau eu}} \qquad Co_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \qquad \frac{\alpha cs}{\alpha eu} = 0.359$$

$tot_i := Cs_i + Eu_i + Co_i$

$$\frac{Eu_N}{Cs_N} = 6.186 \cdot 10^{-4}$$

$out^{\langle 0 \rangle} := yr$ $out^{\langle 1 \rangle} := tot$ WRITEPRN("twop44-52.txt") := out

Dry Well Survey Analysis - Notes

Borehole BY(22-09-02 Total # Surveys 476 Probe Type 04

\# neutron surveys 5 # GR Surveys 468

Log Date: 75-01-09 1st 93-12-28 Last Presentation Plot Dates

(If different from 1st & Last)

Isotope from Spectral Survey: Cs-137 (2000 c/s max 1 FT) Max Survey Depth 100

Contamination Zone Depth(s): 0-10, 10-14, 14-34, 42-64

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-07-21	46	80	
77-06-02	66	100	
77-08-12	17	45	
80-09-17	19	90	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
76-07-21	NO RAD ZONE	85	
77-06-02	WRONG HOLE	95	
77-11-23	NO RAD ZONE	60	
78-08-31	NO RAD ZONE	100	
85-07-31	TRUNCATED	100	MISSING ACTIVITY AT SURFACE
92-02-13	BAD RUN	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
76-07-21	% CLEAN	84	40%	29.5	
76-10-15	AVG BKG	97	60%	39.1	
76-10-21	AVG BKG	98	65%	39.5	
77-06-02	% CLEAN	96	31%	1.3	
77-08-12	% CLEAN	49	30%	34.7	
77-12-01	AVG BKG	98	68%	37.9	
79-10-03	AVG BKG	98	64%	38.5	
92-02-13	% CLEAN	98	0%	0.0	

Analysis Notes

num surveys rejected: (0) ZERO	Background = ~~(0<val<50)~~ 34-42 FT
0-	
Category: (Stable, TF Activity, Undetermined, CHANGED	

Analyst Name Randall Price S/W ver (TFGROSS) V2.20.

Dry Well Survey Analysis - Notes

Borehole BY(22-09-05) Total # Surveys 569 Probe Type 04
neutron surveys 5 # GR Surveys 562
Log Date: 75-01-09 1st 93-12-28 Last Presentation Plot Dates
(If different from 1st & Last)
Isotope from Spectral Survey: CS-137 Max Survey Depth 100
Contamination Zone Depth(s): 40-58, 0-10

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
75-06-05	11	98	
76-07-21	41	42	
76-04-03	13	95	
77-06-02	91	100	
80-09-18	15	95	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-04-09	HI-BKG	100	
79-10-03	HI-BKG	100	
80-10-29	HI-BKG	100	
92-09-29	TOOL FAIL	100	
93-04-13	HI-BKG	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-04-09	AVG BKG	98	71%	32.7	
76-07-21	% CLEAN	45	6%	22.7	
76-10-21	AVG BKG	96	91%	36.7	
77-02-04	AVG BKG	96	86%	40.0	
77-06-02	% CLEAN	96	5%	1.2	
79-03-22	AVG BKG	95	100%	11.6	
80-10-29	AVG BKG	97	7%	48.4	
93-04-13	% CLEAN	56	19%	32.8	

Analysis Notes

num surveys rejected: (0) ZERO	Background = ~~(0<val<50)~~ 12-38
Category: (Stable, TF Activity, Undetermined, CHANGED	

Analyst Name Randall Reno S/W ver (TFGROSS) V2.20.

filein := "GTP40-58.txt" **Well 22-09-05**

A := READPRN(filein) $yr := A^{\langle 1 \rangle}$ $net := A^{\langle 7 \rangle}$ $bkg := A^{\langle 6 \rangle}$ $max := A^{\langle 4 \rangle}$

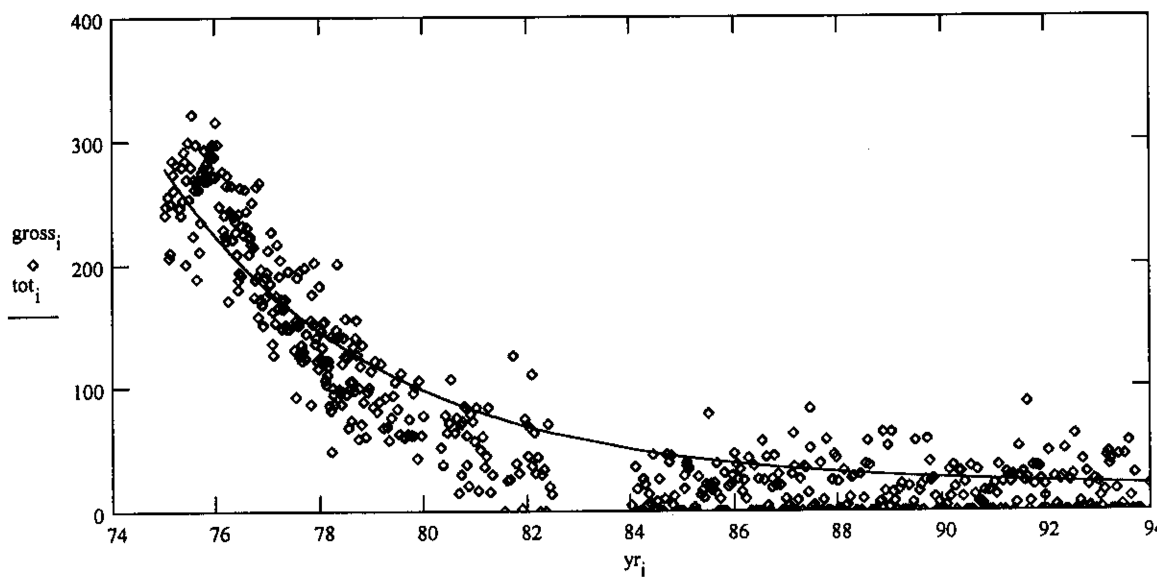
N := last(yr) N = 548 i := 0..N k := 0..300 j := 0..299

1st Isotope is Cs (30.17 yrs) $\tau co := 30.17$ aco := 30

2nd Isotope is Sb-125 (2.77 yrs) $\tau 2 := 2.77$ a2 := 250

$Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := a2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$gross_i := net_i$ This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}} \right] \right]^2$$

Given

ssq(aco, a2) = 0 1 = 1

$$\begin{bmatrix} \alpha co \\ \alpha 2 \end{bmatrix} := Minerr(aco, a2)$$

$\alpha co = 29.993$ $\alpha 2 = 250.811$

Cs-137 Sb-125 $\frac{\alpha co}{\alpha 2} = 0.12$

$Co_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := \alpha 2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$out^{\langle 0 \rangle} := yr$ $out^{\langle 1 \rangle} := tot$ WRITEPRN("twop.txt") := out Ratio Sb/Cs $\frac{X2_N}{Co_N} = 0.112$

Dry Well Survey Analysis - Notes

Borehole BY(22-09-07) Total # Surveys 487 Probe Type 04

neutron surveys 5 # GR Surveys 481

Log Date: 75-01-10 1st 93-12-28 Last Presentation Plot Dates 75-05-16

(If different from 1st & Last)

Isotope from Spectral Survey: CS (6-20FT) Co (25-85FT) Max Survey Depth 97

Contamination Zone Depth(s): 20-64FT (GTP~0 (1988-93))

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-07-21	17	60	
76-07-28	54	80	
77-06-02	47	95	
77-08-12	22	90	
80-09-17	22	90	
82-01-27	18	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-03-27	BAD SURVEY	170	
75-06-05	HI-BKG	100	
76-07-28	BAD SURVEY	70	
78-03-22	BAD SURVEY	100	
79-10-03	HI-BKG	100	
92-02-13	TOOL FAIL	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-06-05	0% CLEAN	97	0%	0.0	
76-09-09	0% CLEAN	96	42%	71.2	
77-06-02	AVG BKG	95	50%	2.0	
78-03-22	AVG BKG	96	84%	18.1	
79-10-03	% CLEAN	96	7%	45.4	
80-09-17	% CLEAN	89	41%	31.2	
82-01-27	AVG BKG	95	80%	18.0	
92-02-13	0% CLEAN	96	0%	0.0	

Analysis Notes

num surveys rejected: (0) ZERO Background = (0<val<50)

ALSO FIT GTR FOR 3-25 TO 1/85 (RUSB Co)

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V2.20.

filein := "two20-64.txt" **Well 22-09-07**

A := READPRN(filein) $yr := A^{\langle 1 \rangle}$ $net := A^{\langle 7 \rangle}$ $bkg := A^{\langle 6 \rangle}$ $max := A^{\langle 4 \rangle}$

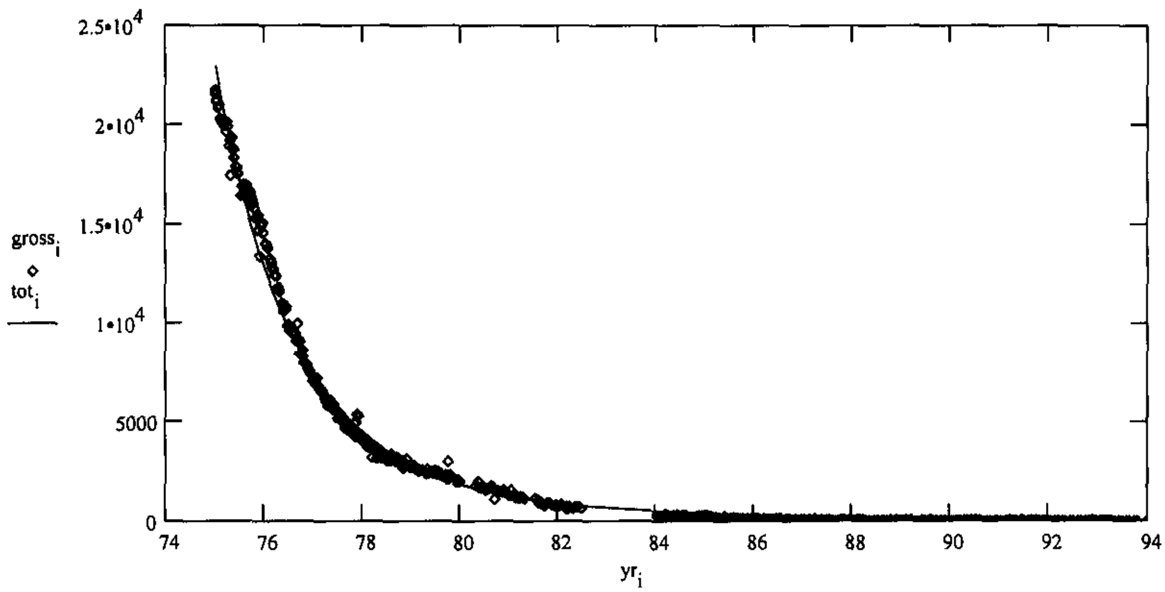
N := last(yr) N = 463 i := 0 .. N k := 0 .. 300 j := 0 .. 299

1st Isotope is Sb125 (2.77 yrs) $\tau co := 2.77$ aco := 4300

2nd Isotope is Ru106 (1.02 yrs) $\tau 2 := 1.02$ a2 := 19000

$Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{ln(2)}{\tau co}}$ $X2_i := a2 \cdot e^{-(yr_i - 75)\cdot\frac{ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$gross_i := net_i$ This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{ln(2)}{\tau co}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{ln(2)}{\tau 2}}\right]\right]^2$$

Given

ssq(aco, a2) = 0 1 = 1

$\begin{bmatrix} \alpha co \\ \alpha 2 \end{bmatrix}$:= Minerr(aco, a2)

Sb $\alpha co = 4.289 \cdot 10^3$ Ru $\alpha 2 = 1.917 \cdot 10^4$

$Co_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{ln(2)}{\tau co}}$ $X2_i := \alpha 2 \cdot e^{-(yr_i - 75)\cdot\frac{ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$ Sb/Ru $\frac{\alpha co}{\alpha 2} = 0.224$

$out^{\langle 0 \rangle} := yr$ $out^{\langle 1 \rangle} := tot$ WRITEPRN("twop.txt") := out Ratio Sb/Ru $\frac{Co_N}{X2_N} = 778.729$ Sb Ru

filein := "GTP20-40.txt" **Well 22-09-07**

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

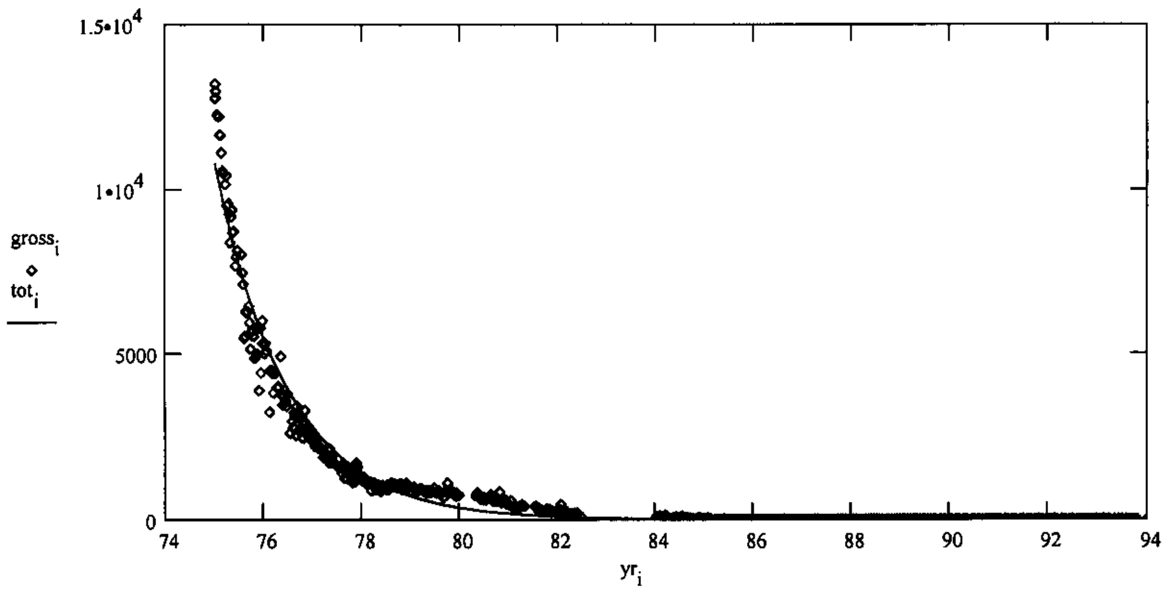
N := last(yr) N = 465 i := 0 .. N k := 0 .. 300 j := 0 .. 299

1st Isotope is Sb125 (2.77 yrs) $\tau co := 2.77$ aco := 0

2nd Isotope is Ru106 (1.02 yrs) $\tau 2 := 1.02$ a2 := 11000

$Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := a2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$gross_i := net_i$ This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}\right]\right]^2$$

Given

ssq(aco, a2) = 0 1 = 1

$\begin{bmatrix} \alpha co \\ \alpha 2 \end{bmatrix}$:= Minerr(aco, a2)

$\alpha co = -453.63$ $\alpha 2 = 1.17 \cdot 10^4$

$Co_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := \alpha 2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$ $\frac{\alpha co}{\alpha 2} = -0.039$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop.txt") := out Ratio Sb/Ru $\frac{Co_N}{X2_N} = -134.997$

filein := "GTP40-50.txt" **Well 22-09-07**

A := READPRN(filein) $yr := A^{\langle 1\rangle}$ $net := A^{\langle 7\rangle}$ $bkg := A^{\langle 6\rangle}$ $max := A^{\langle 4\rangle}$

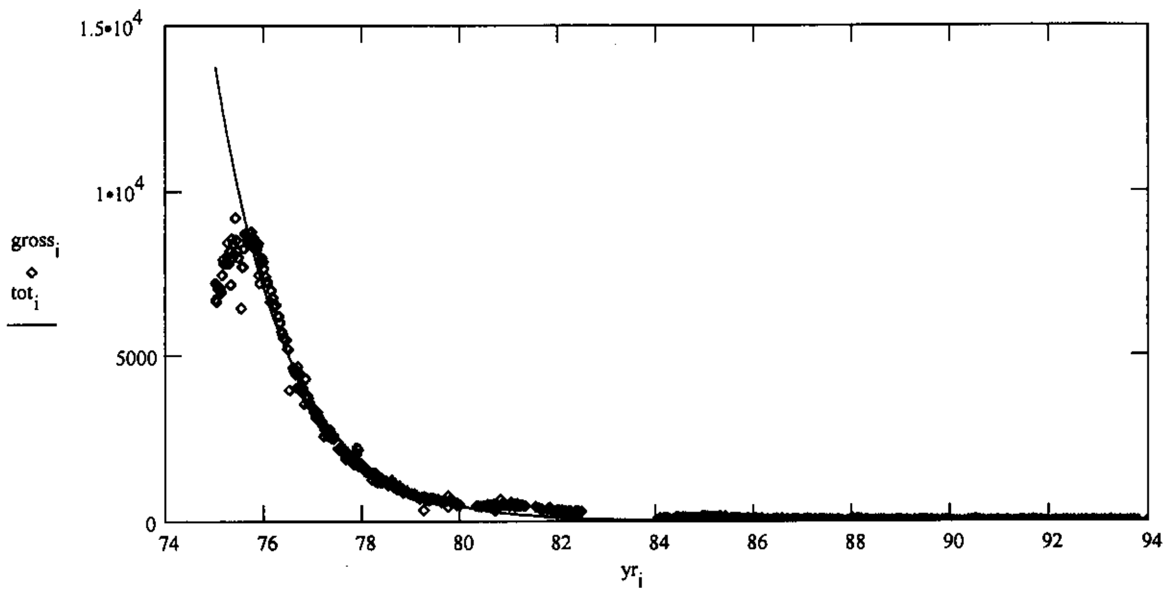
N := last(yr) N = 472 i := 0 .. N k := 0 .. 300 j := 0 .. 299

1st Isotope is Sb125 (2.77 yrs) $\tau co := 2.77$ aco := 0

2nd Isotope is Ru106 (1.02 yrs) $\tau 2 := 1.02$ a2 := 14000

$$Co_i := aco\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \qquad X2_i := a2\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}} \qquad tot_i := Co_i + X2_i$$

$gross_i := net_i$ This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}\right]\right]^2$$

Given

ssq(aco, a2) = 0 1 = 1

$$\begin{bmatrix}\alpha co\\ \alpha 2\end{bmatrix} := Minerr(aco, a2)$$

$\alpha co = 2.009\cdot 10^3$ $\alpha 2 = 8.467\cdot 10^3$

$\frac{\alpha co}{\alpha 2} = 0.237$

$$Co_i := \alpha co\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \qquad X2_i := \alpha 2\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}} \qquad tot_i := Co_i + X2_i$$

$out^{\langle 0\rangle} := yr$ $out^{\langle 1\rangle} := tot$ WRITEPRN("twop.txt") := out Ratio Sb/Ru $\frac{Co_N}{X2_N} = 825.736$

filein := "GTP50-64.txt" **Well 22-09-07**

A := READPRN(filein) $yr := A^{<1>}$ $net := A^{<7>}$ $bkg := A^{<6>}$ $max := A^{<4>}$

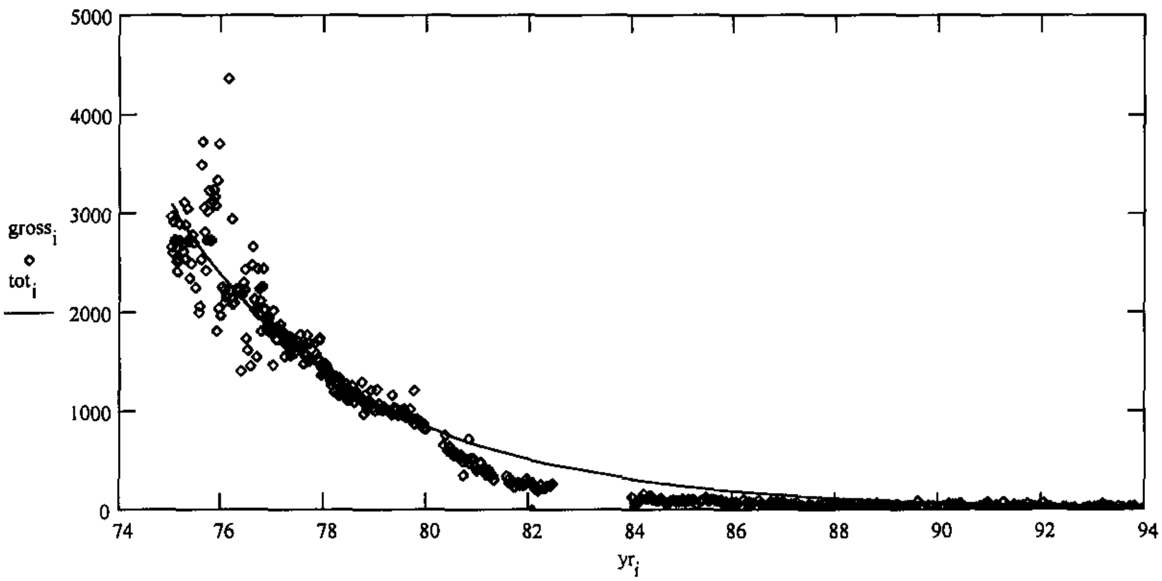
N := last(yr) N = 469 i := 0..N k := 0..300 j := 0..299

1st Isotope is Sb125 (2.77 yrs) $\tau co := 2.77$ aco := 2930

2nd Isotope is Ru106 (1.02 yrs) $\tau 2 := 1.02$ a2 := 180

$Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := a2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$gross_i := net_i$ This data edited for spurious points



$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}} \right] \right]^2$$

Given

ssq(aco, a2)=0 1=1

$$\begin{bmatrix} \alpha co \\ \alpha 2 \end{bmatrix} := Minerr(aco, a2)$$

$\alpha co = 2.921 \cdot 10^3$ $\alpha 2 = 183.627$

$\frac{\alpha co}{\alpha 2} = 15.91$

$Co_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := \alpha 2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$out^{<0>} := yr$ $out^{<1>} := tot$ WRITEPRN("twop.txt") := out Ratio Sb/Ru $\frac{Co_N}{X2_N} = 5.538 \cdot 10^4$

Dry Well Survey Analysis - Notes

04 = 368
14 = 29 (1980)

Borehole B4(22-09-08) Total # Surveys 402 Probe Type 04

\# neutron surveys 4 # GR Surveys 368

Log Date: 80-01-24 1st 93-12-28 Last Presentation Plot Dates

(If different from 1st & Last) Max Survey Depth 98

Isotope from Spectral Survey: Cs (1200 pCi/g @ 24 FT)

Contamination Zone Depth(s): 16-30, 43-52, 76-~~84~~ 90

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
80-09-17	21	95	

HI-ZONES.Txt

	Survey Date	Reason Selected	approx #Samp's	Comment
	89-10-17	RAD Zone Chg	100	
04	90-06-15A	RAD Zone Chg	100	
	91-02-19A	Big RAD Zone	100	
	93-04-13	BAD SURVEY	100	
	93-04-27B	BAD SURVEY	100	
14	80-01-22A	BAD SURVEY	50	

BackGnd.Txt

	Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
	80-09-17	% Clean	93	66%	31.2	
04	80-11-05	AVG BKG	97	88%	34.5	
	81-07-23	AVG BKG	97	84%	34.1	
	93-04-13	% CLEAN	96	10%	44.5	
14	80-02-21	AVG BKG	96	95%	6.2	

Analysis Notes

num surveys rejected: (0) ZERO	Background = ~~(0<val<50)~~ 55-74
16-30 FT (HIGH C/S - TOOL DT PROBS)	
Category: (Stable, TF Activity, Undetermined, CHANGED	

Analyst Name Randall Price S/W ver (TFGROSS) V2.20.

Dry Well Survey Analysis - Notes

Borehole B4(22-09-11) Total # Surveys 559 Probe Type 04
\# neutron surveys 5 # GR Surveys 532
Log Date: 75-01-09 1st 93-12-29 Last Presentation Plot Dates
(If different from 1st & Last)
Isotope from Spectral Survey: Cs (0-35FT) Co 21-50FT Max Survey Depth 100
Contamination Zone Depth(s): 0-10, 16-25, 38-52FT

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-09-03	17	100	
77-06-02	74	100	
80-09-17	13	90	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
78-03-22A	BAD SURVEY	98	
79-04-06	SHORT SURVEY	40	
85-12-30A	HI-BKG	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
76-10-15	AVG BKG	98	63%	42.4	
76-12-16	AVG BKG	98	62%	41.2	
77-05-05	AVG BKG	96	78%	38.0	
77-06-02	AVG BKG	98	24%	1.5	
78-08-10	AVG BKG	97	83%	36.2	
85-08-27	AVG BKG	98	8.9%	19.7	

Analysis Notes

num surveys rejected: (0) ZERO Background = (0<~~val~~<50) 60-90FT
0-10 TF ACTIVITY
TABLE 16-25FT (PROBABLY 3-ISOTOPE DECAY) Cs & Sb
CS=106, ~~Sb~~125=214 AT 1/1975 Sb/Cs = 0.028 @ 12-93
38-52 DECAY > Ru-106 (1975-1976); BUT RATE DECR 1975-76
IS GREATER THAN Ru-106 (DATA ABOVE DECAY CURVE)

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V2.20.

filein := "GTP16-25.txt"

Well 22-09-11

A := READPRN(filein) $\quad yr := A^{\langle 1\rangle} \quad net := A^{\langle 7\rangle} \quad bkg := A^{\langle 6\rangle} \quad max := A^{\langle 4\rangle}$

N := last(yr) $\quad$ N = 545 $\quad$ i := 0 .. N $\quad$ k := 0 .. 300 $\quad$ j := 0 .. 299

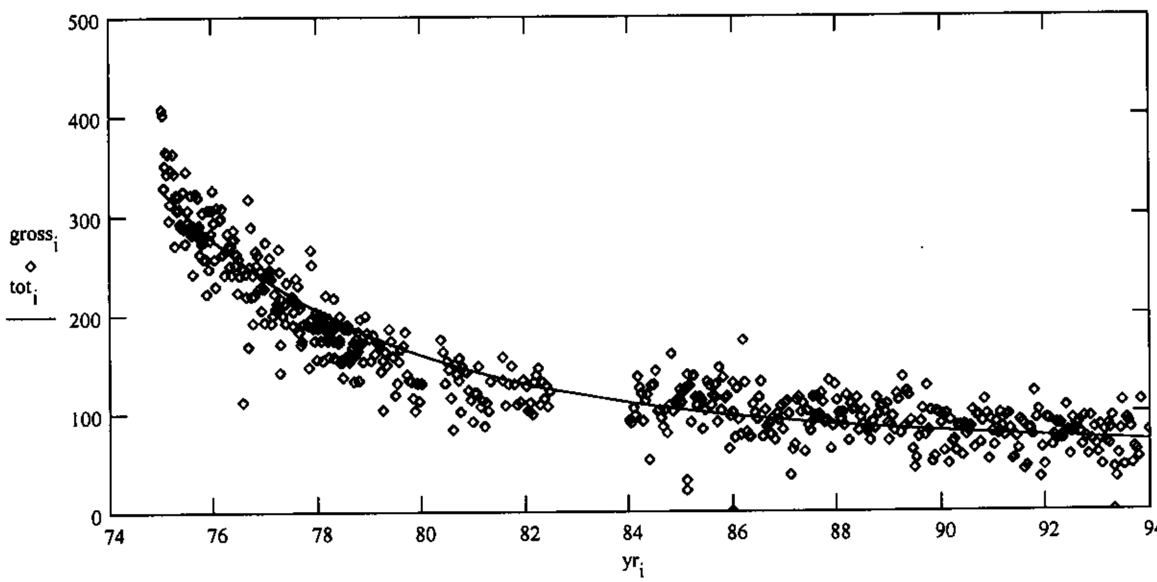
Sb-125

$\tau co := 2.77 \quad \tau cs := 30.17 \quad aco := 220 \quad acs := 108$

$$Cs_i := acs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \qquad Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \qquad tot_i := Cs_i + Co_i$$

$gross_i := net_i$

This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} + a3 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \right] \right]^2$$

Given

ssq(acs, aco) = 0 $\qquad$ 1 = 1

$$\begin{bmatrix} \alpha cs \\ \alpha co \end{bmatrix} := Minerr(acs, aco) \qquad \boxed{\alpha cs = 105.825} \qquad \boxed{\cancel{\alpha co} = 214.287}$$

Sb-125

$$Cs_i := \alpha cs \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau cs}} \qquad Eu_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} \qquad tot_i := Cs_i + Co_i \qquad \frac{\alpha cs}{\alpha co} = 0.494$$

Sb-125

$out^{\langle 0\rangle} := yr \qquad out^{\langle 1\rangle} := tot \qquad$ WRITEPRN("twop.txt") := out $\qquad \frac{\cancel{Co_N}}{Cs_N} = 0.028$

Borehole 22-10-05

Contamination (Co-60) from 45 to 55 feet is Stable
Contamination (Co-60) from 55 to 75 feet **UNSTABLE** early

Grade Thickness Product for the radioactive zone (45-55 feet) is decreasing within observed systematic limitations at a rate consistent with the decay of Co-60 (identified from HPGe detector) between 1975 and 1994.

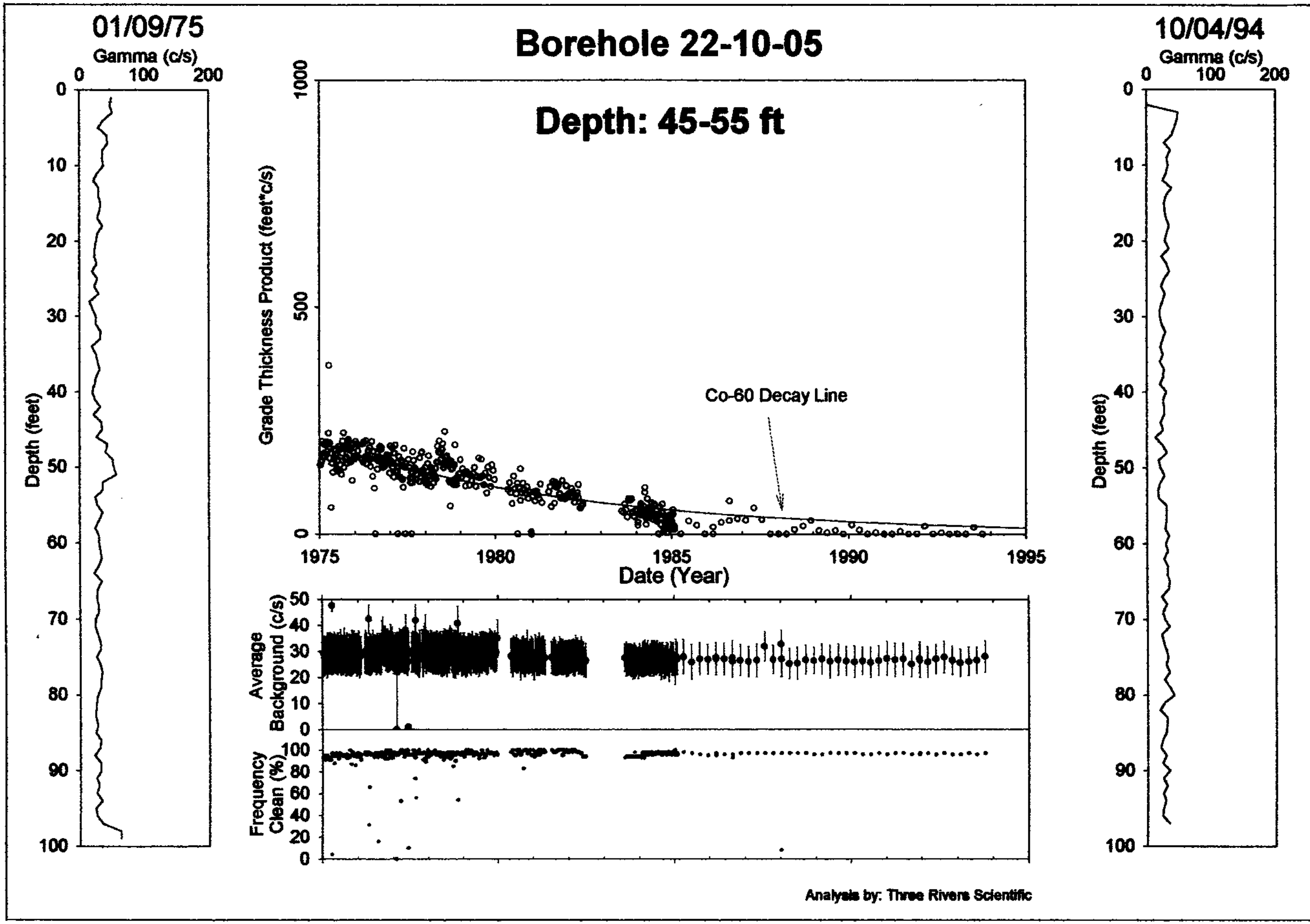
Grade Thickness Product for the radioactive zone (55-75 feet) is decreasing within observed systematic limitations at a rate consistent with the decay of Co-60 (identified from HPGe detector) from 1979 to 1994. However, from 1975 to 1979 the radiation zone was below the Co-60 decay rate (i.e. increasing radioactive contaminants.) The activity in the radiation zone is at low levels.

Gross Gamma Survey Information

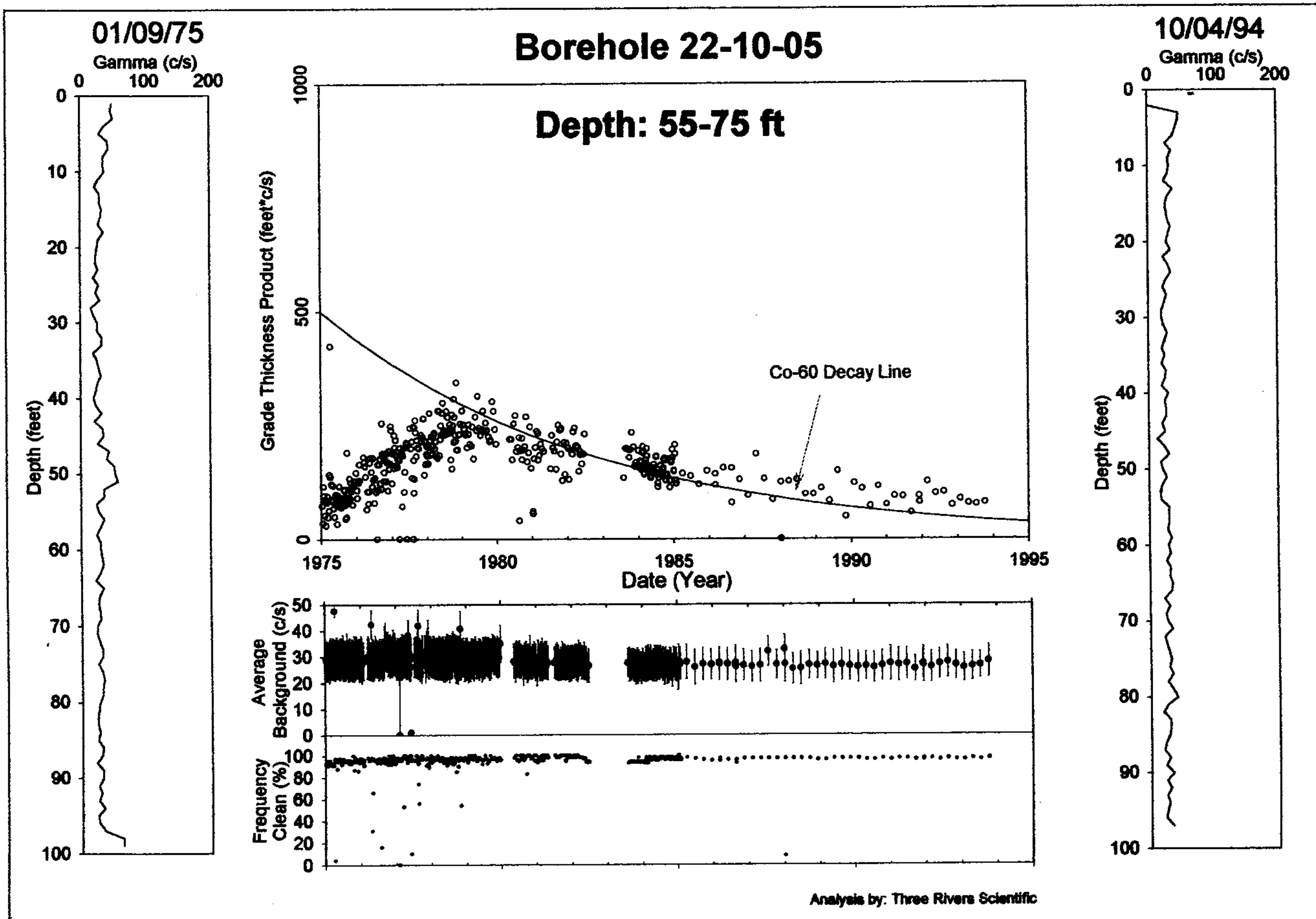
Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (4 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	10/4/1993
Number Surveys :	400

Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	20 to 40 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	45-55 feet is Stable 55-75 feet was UNSTABLE early
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



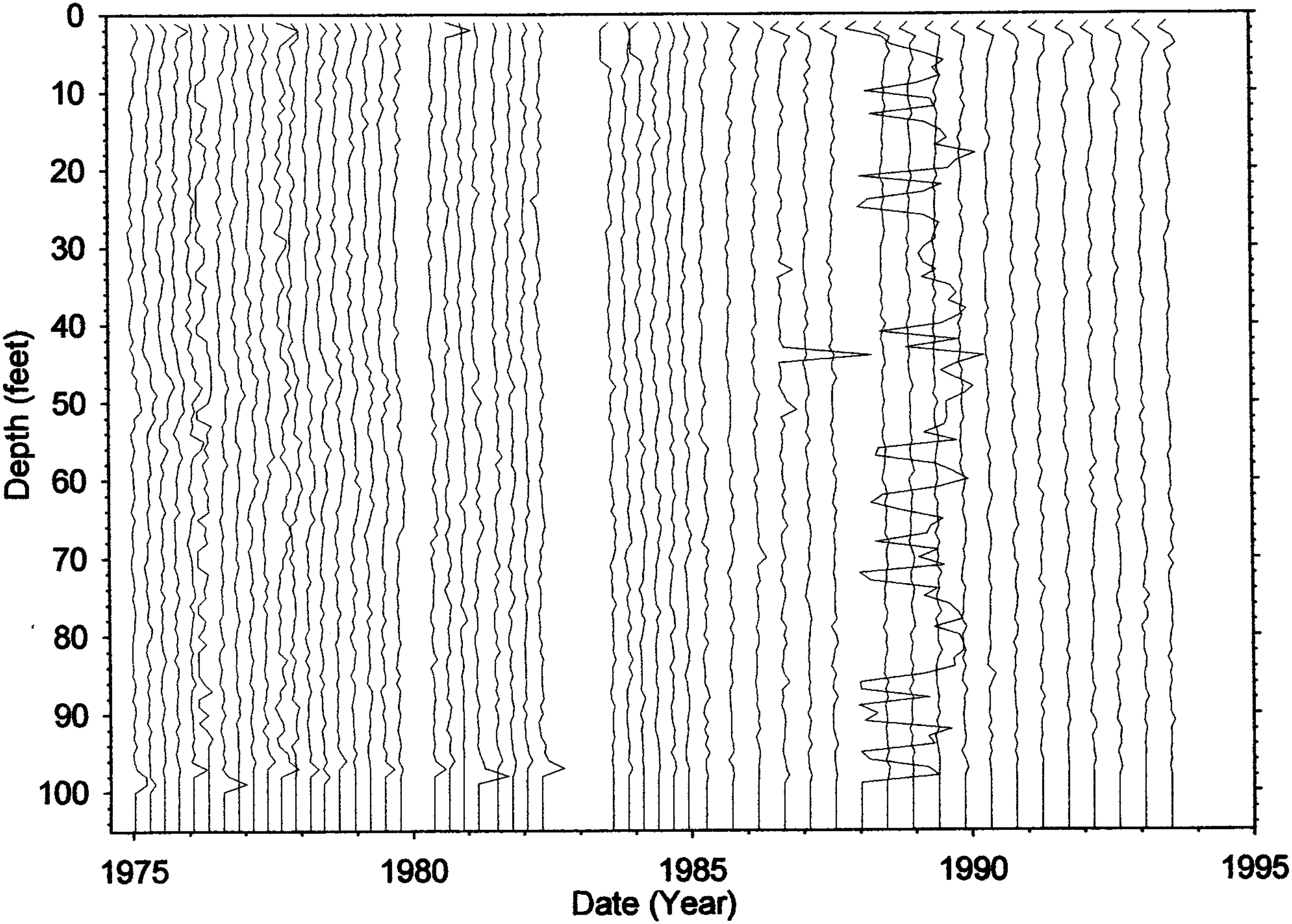
01/09/75
Gamma (c/s)
Depth (feet)
Borehole 22-10-05
Depth: 45-55 ft
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
10/04/94
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific



Borehole 22-10-05
Depth: 55-75 ft
01/09/75
Gamma (c/s)
0
100
200
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
Grade Thickness Product (feet*c/s)
0
500
1000
Co-60 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average Background (c/s)
0
10
20
30
40
50
Frequency Clean (%)
0
20
40
60
80
100
10/04/94
Gamma (c/s)
0
100
200
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
Analysis by: Three Rivers Scientific

00 474

Borehole 22-10-05



00 475

HNF-3532 -REV0

Borehole 22-10-07

Contamination (Co-60) from 45 to 65 feet <u>UNSTABLE</u>

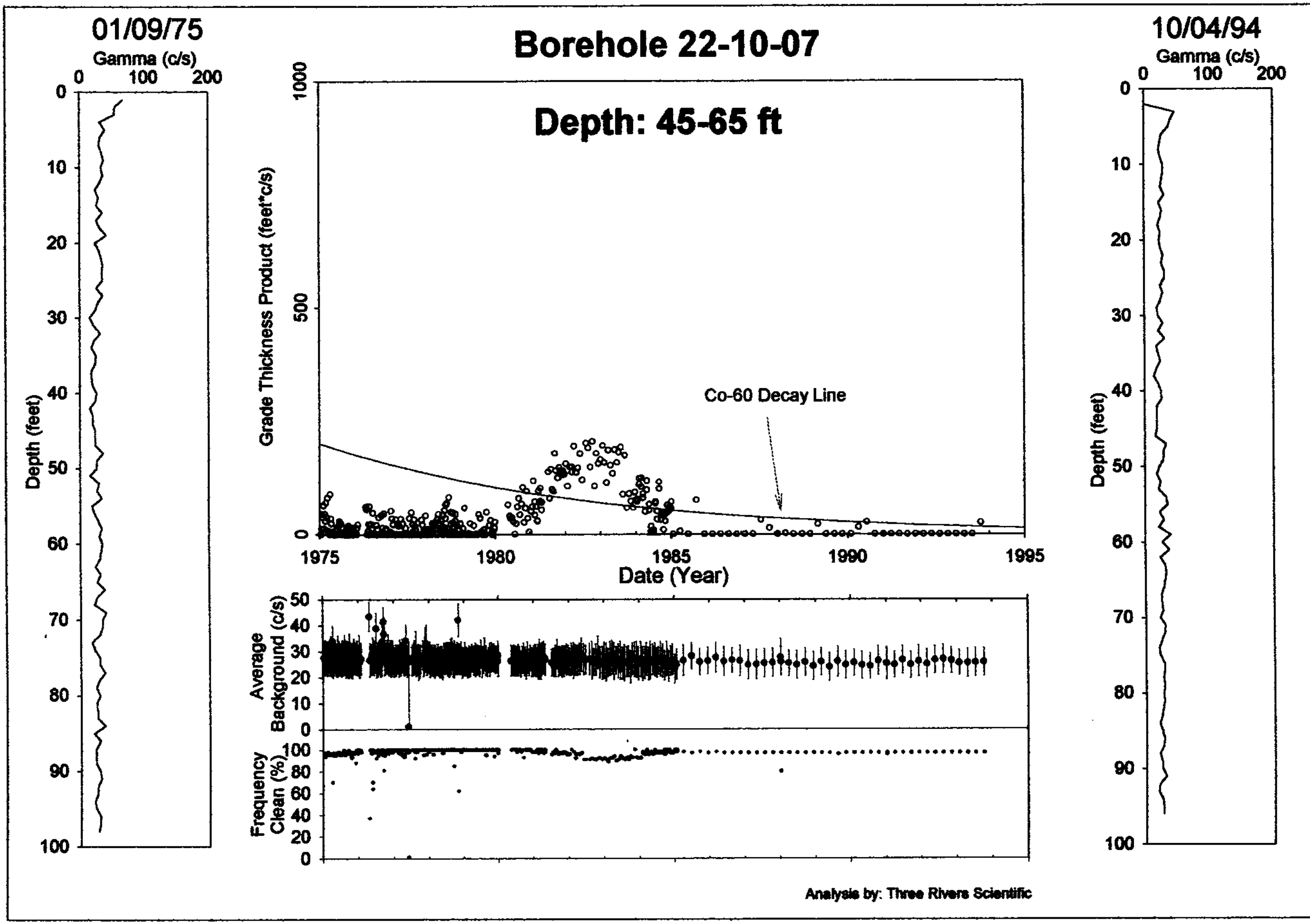
Grade Thickness Product for the radioactive zone (45-65 feet) shows only background activity except for a brief time period (1980-1985) in which radioactive contaminants migrated past the gamma probe investigation radius. During the time period of 1980 to 1983 the contaminant concentration was increasing, followed by a brief period from 1983 to 1985 of decreasing activity. The rate of decrease of the grade thickness product does not appear to be the decay of a stable radionuclide. A half life decay curve for Co-60 (identified from HPGe detector) is shown to demonstrate that the radioactive contaminants were not stable.

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (4 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	10/4/1993
Number Surveys :	377

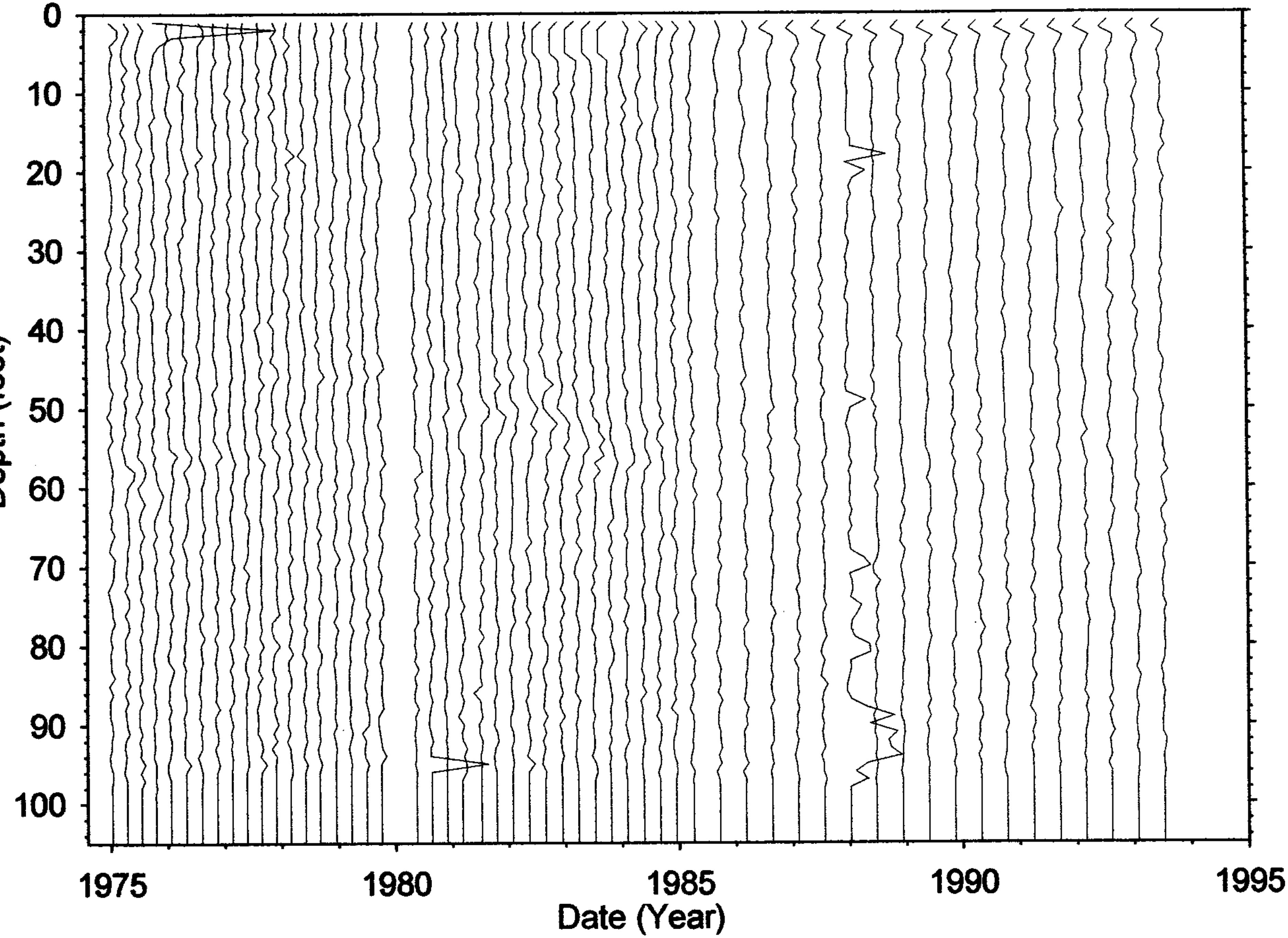
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	Threshold (0< val < 50)
Depth(s) where Contamination Identified in Gross Gamma Surveys :	45-65 feet <u>UNSTABLE</u>
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific

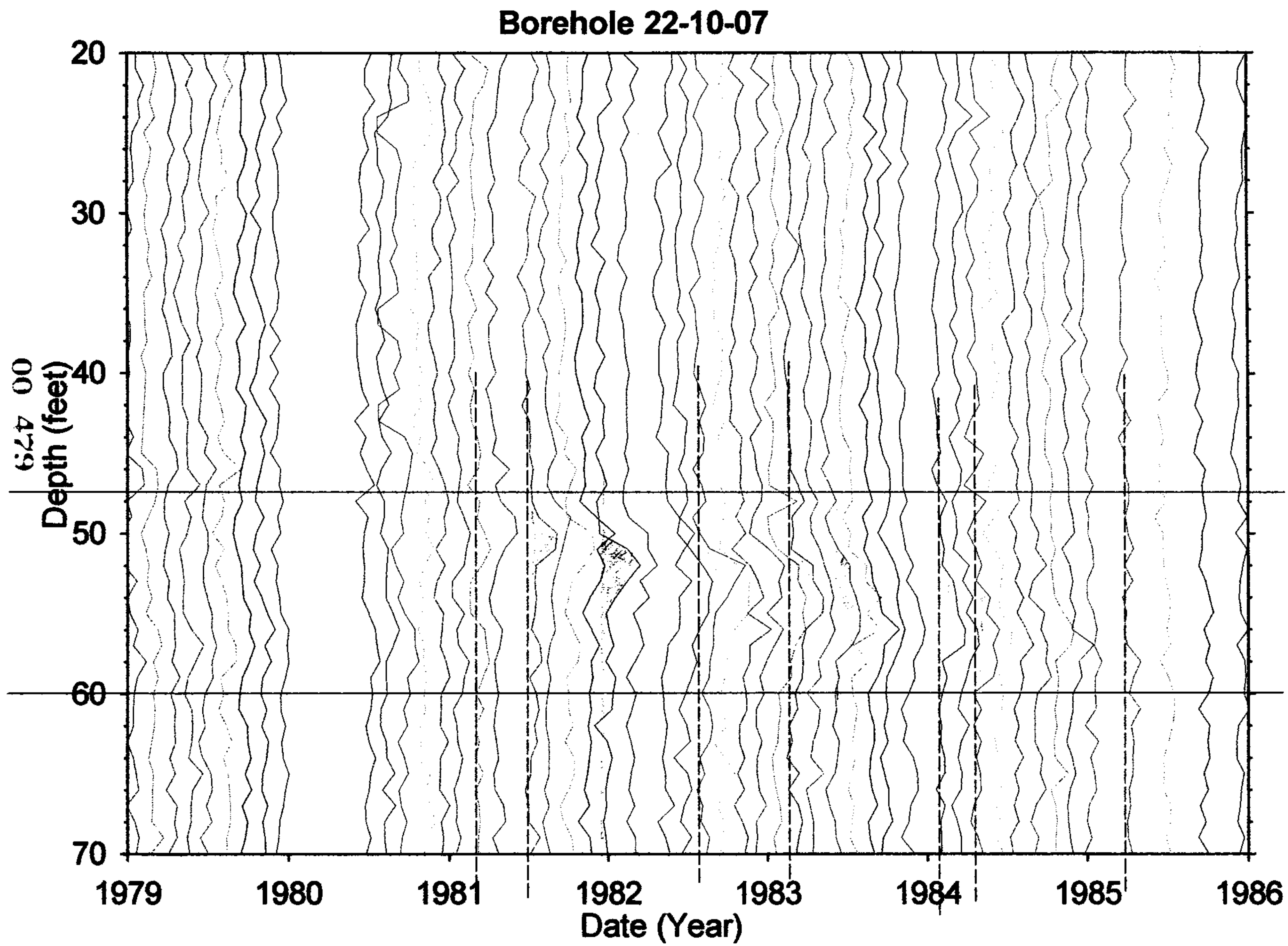


Borehole 22-10-07
01/09/75
Gamma (c/s)
Depth (feet)
Depth: 45-65 ft
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
10/04/94
Gamma (c/s)
Depth (feet)
Analysis by: Three Rivers Scientific

Borehole 22-10-07



HNF-3532 -REV0



HNF-3532 -REV0

Borehole 22-10-09

Contamination (Cs-137) from 0 to 10 feet is TF Activity

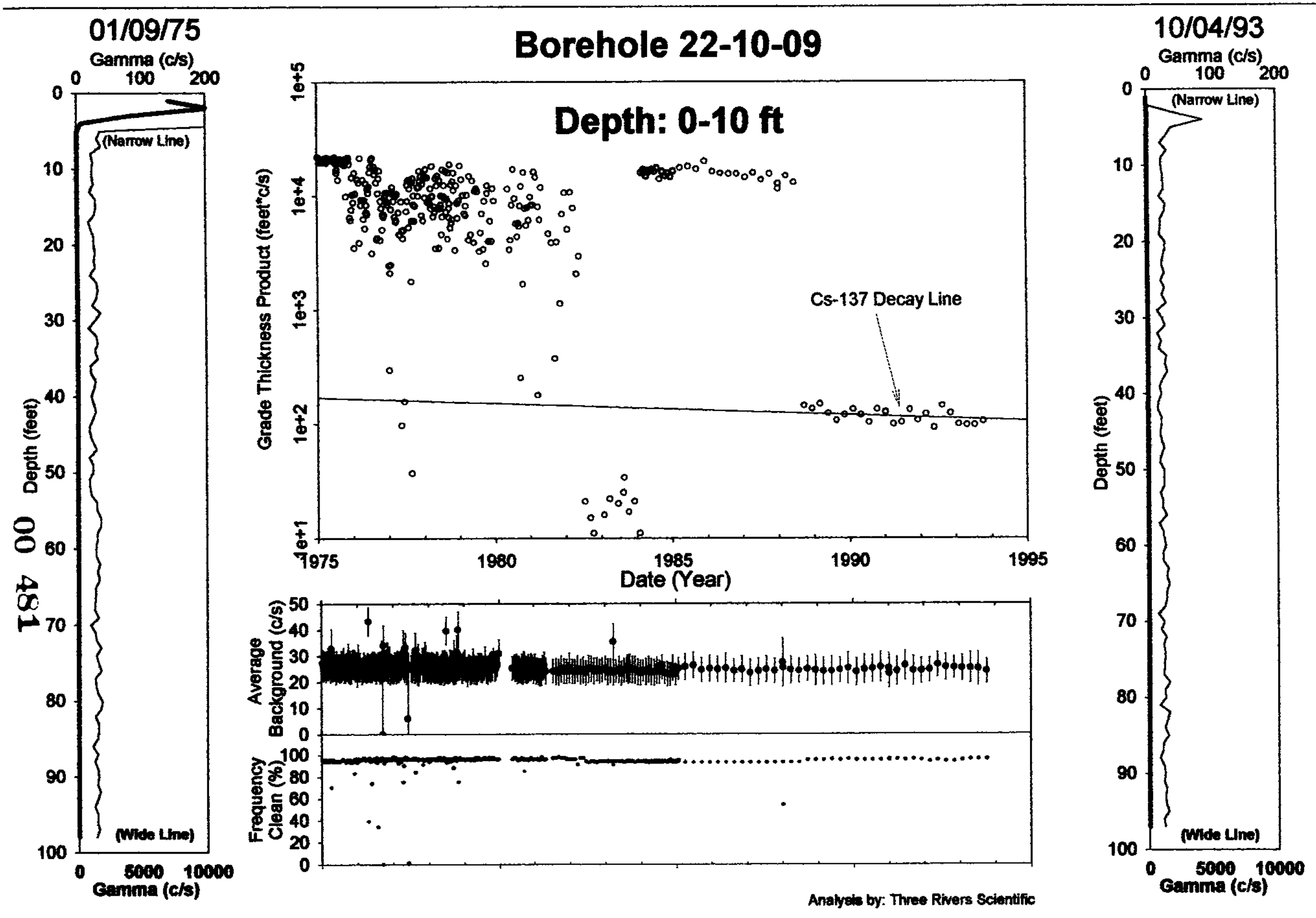
Grade Thickness Product from 0 to 10 feet is erratic for the 20 years of survey data and is categorized as Tank Farm activity. Changes in the logging procedure when logging surface radiation zones perturbs reliable calculation of the Grade Thickness Product. A decay line for Cs-137 (identified from HPGe detector) fitted to the last few survey values is presented.

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (5 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	10/4/1993
Number Surveys :	364

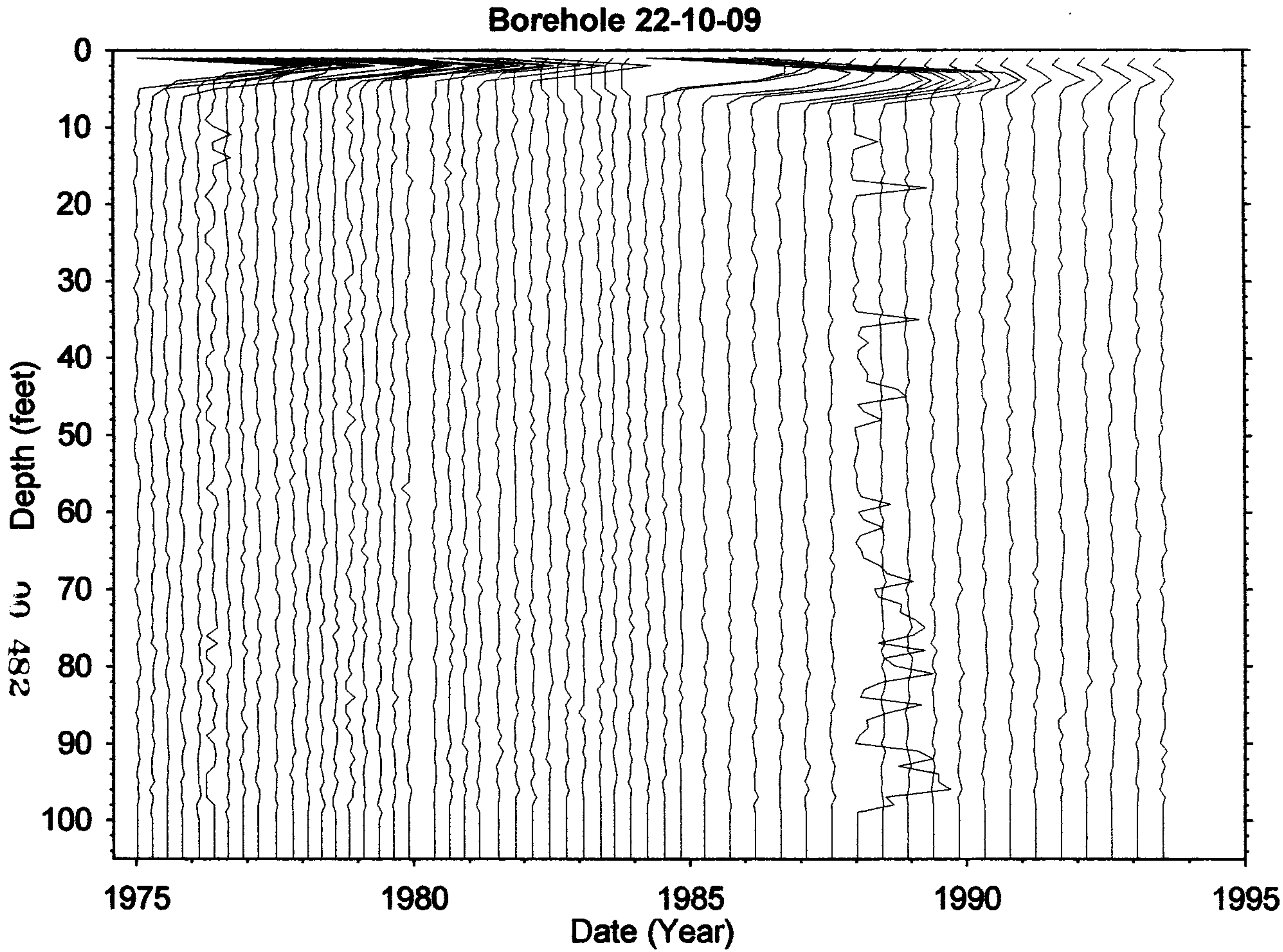
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	10 to 40 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	**0-10 feet is TF Activity**
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



00 481

HNF-3532 -REV0


Borehole 22-10-09
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
1975
1980
1985
1990
1995
Date (Year)

Borehole 22-10-10

Contamination (Co-60) from 58 to 76 feet <u>UNSTABLE</u> early

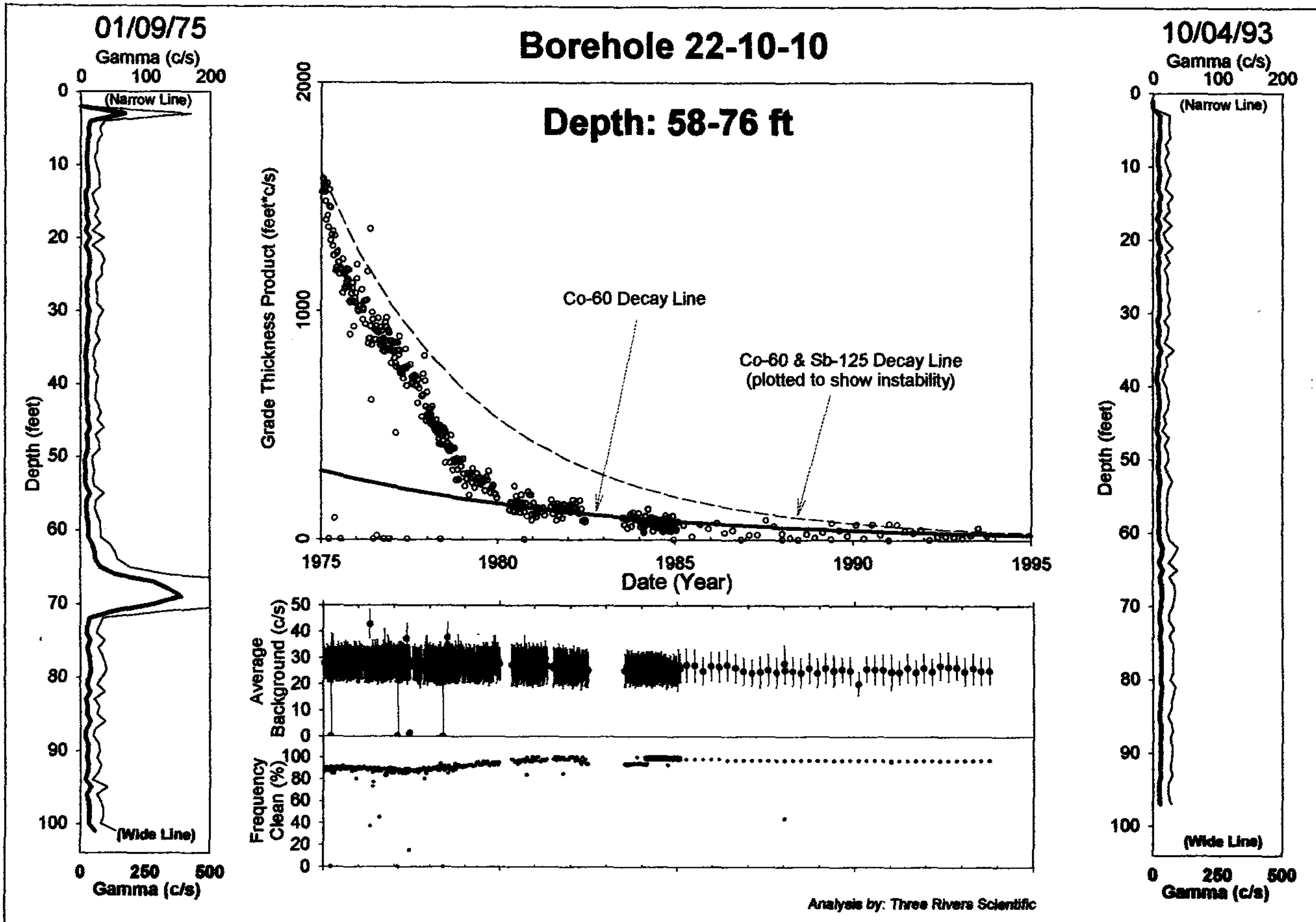
Grade Thickness Product for the radioactive zone (58-76 feet) exhibits a rate of change that does not fit the gross gamma response characteristics for a stable radioactive zone. The high rate of decrease from 1975 to 1985 in the gamma-ray activity is confirmed by multiple and frequent surveillance logs. The conclusion is that the radioactive zone (58-76 feet) from 1975 to 1980 was not stable. The Co-60 (identified from HPGe detector) decay line fits the grade thickness product data from 1980 to 1995 and is used to establish the later stability. A combined decay line of Sb-125 (hypothesis) & Co-60 is presented on the plot for reference to show the poor fit.

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (4 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	01/09/1975
Last Survey Date :	10/04/1993
Number Surveys :	406

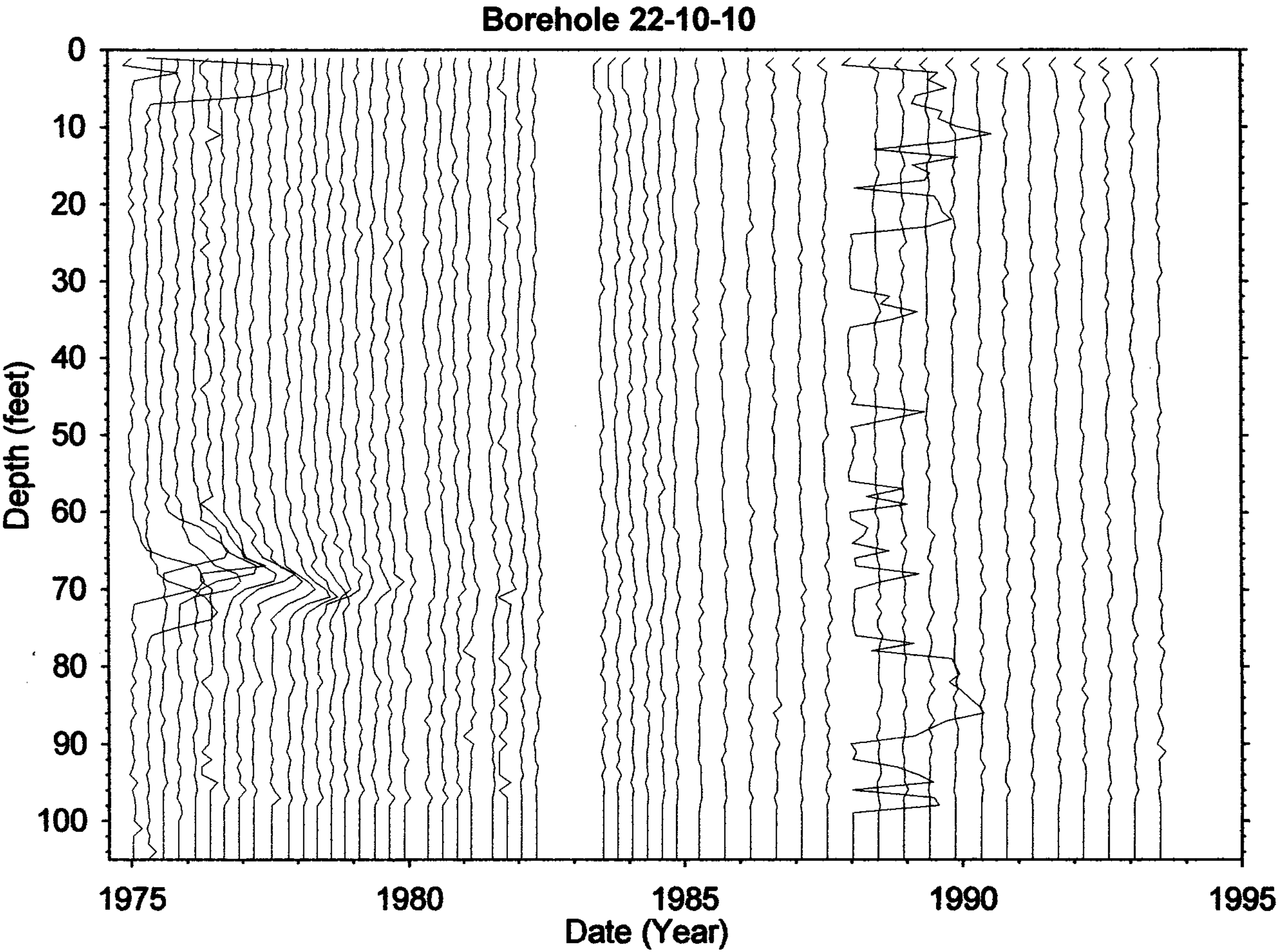
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	80 to 95 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	58-76 feet UNSTABLE early
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



HNF-3532 - REV0

00 484



HNF-3532 -REV0

00 485

Dry Well Survey Analysis - Notes

Borehole BY(22-10-05) Total # Surveys 406 Probe Type 04

\# neutron surveys 4 # GR Surveys 400

Log Date: 75-01-09 1st 93-10-04 Last Presentation Plot Dates

(If different from 1st & Last)

Isotope from Spectral Survey: Co60 (45-75') <1 pCi/g Max Survey Depth 100

Contamination Zone Depth(s): 45-55, 55-75 FT

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-04-29	31	92	
76-07-28	56	90	
77-06-02	86	100	
80-09-18	15	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-04-09	HI BKG	100	
76-07-28	BAD SURVEY	90	
77-02-03	TOOL FAIL	100	
77-03-16A	BAD SURVEY	100	
78-11-01	HI BKG	100	
88-01-06	TOOL FAIL	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-04-09	AVG BKG	98	4%	47.5	
76-04-22	% CLEAN	95	31%	42.4	
76-07-28	% CLEAN	87	16%	28.0	
77-02-03	AVG BKG	97	0%	0.0	
77-06-02	% CLEAN	96	10%	1.0	
77-08-18	% CLEAN	97	56%	41.9	
78-11-01	% CLEAN	97	54%	40.7	
88-01-06	% CLEAN	98	8%	32.8	

Analysis Notes

num surveys rejected: (0) ZERO Background ~~(0<val<50)~~ 20-40

POSSIBLE LOW LEVEL ZONE (BEGIN 1975.5 AT 56 FT - WAS MOVING DOWN)

DEPTH SHIFT NOT POSSIBLE.

GTP- ANALYSIS CONFIRMS DOWNWARD MOVEMENT (1975 TO 1980)

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V2.20

Dry Well Survey Analysis - Notes

Borehole B4(22-10-07) Total # Surveys 381 Probe Type 04

\# neutron surveys 4 # GR Surveys 377

Log Date: 75-01-09 1st 93-10-04 Last Presentation Plot Dates

(If different from 1st & Last)

Isotope from Spectral Survey: Co-60 Max Survey Depth 100

Contamination Zone Depth(s): 45-60 FT

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-05-26	31	95	
77-06-02A	94	100	
78-09-14	14	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
76-04-22	HI-BKG	100	
78-11-01	HI-BKG	100	
88-01-06	NOISY SURV	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-07-31	LENGTH	54	100%	27.1	
76-04-22	AVG BKG	94	37%	43.4	
76-05-26	% CLEAN	92	64%	27.1	
76-07-02	AVG BKG	91	92%	38.9	
76-09-16	AVG BKG	95	81%	41.4	
76-09-22	AVG BKG	95	95%	36.7	
77-06-02	% CLEAN	95	1%	1.0	
78-11-01	AVG BKG	96	60%	42.0	

Analysis Notes

num surveys rejected: (0) Background = ~~(0<val<50)~~ 65-90 FT

Low Level Rad Zone (57')

RADIOACTIVE ZONE (45-60 FT) MIGRATED THRU 1980 TO 1995

DOWNWARD MOVEMENT IS SEEN IN STACK PLOT

(FROM 1981 @ 50 FT TO 1984 @ 59 FT)

Category: (Stable, TF Activity, Undetermined, CHANGED)

Analyst Name Randall Price S/W ver (TFGROSS) V2.20

Dry Well Survey Analysis - Notes

Borehole BY (22-10-09) Total # Surveys 370 Probe Type 04
neutron surveys 5 # GR Surveys 364
Log Date: 75-01-09 1st 93-10-04 Last Presentation Plot Dates
(If different from 1st & Last)
Isotope from Spectral Survey: Cs <5P Ci/g 0-5FT Max Survey Depth 100
Contamination Zone Depth(s): 0-10 FT

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
75-12-03	13	100	
76-05-26	20	100	
76-07-28	45	65	
77-06-02	95	100	
80-09-17	13	95	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-04-09	HI BKG	100	
76-04-22	HI BKG	100	
76-09-16	HI BKG	100	
77-08-17	BAD SURVEY	95	
78-11-01	HI BKG	100	
— LOST	RAD ZONE	82-06-15 TO 84-02-23	
88-01-06	TOOL FAIL	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
76-04-22	AVG BKG	97	39%	43.2	
76-07-28	% CLEAN	69	34%	26.0	
76-09-16	% CLEAN	98	0%	0.0	
77-06-02	AVG BKG	98	1%	6.0	
78-06-28	AVG BKG	97	93%	39.6	
78-11-01	AVG BKG	98	75%	40.0	
88-01-06	% CLEAN	98	54%	27.4	

Analysis Notes

num surveys rejected: (0) ZERO Background = (0<~~val~~<50) 10-40

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V2.20.

Dry Well Survey Analysis - Notes

Borehole BY(22-10-10) Total # Surveys 410 Probe Type 04

\# neutron surveys 4 # GR Surveys 406

Log Date: 75-01-04 1st 93-10-04 Last Presentation Plot Dates

(If different from 1st & Last)

Isotope from Spectral Survey: Max Survey Depth 100

Contamination Zone Depth(s): 58-76 FT

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
75-12-03	13	100	
76-05-26	13	95	
76-07-28	45	85	
77-06-02	82	100	
81-10-13	13	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-03-20	TOOL FAIL	95	
75-05-15	NO RADZONES	170	
76-04-22	HI BKG	100	
76-07-28	BAD SURVEY	90	
77-02-03	HI BKG	105	
78-05-11	TOOL FAIL	100	
88-01-06	TOOL FAIL	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-05-15	LENGTH	198	89%	26.9	
76-04-22	AVG BKG	95	37%	42.8	
76-07-28	% CLEAN	86	45%	22.1	
77-02-03	% CLEAN	101	0%	0.0	
77-05-05	AVG BKG	95	87%	37.2	
78-05-11	% CLEAN	98	0%	0.0	
78-06-28	AVG BKG	96	85%	37.8	
88-01-06	% CLEAN	98	44%	22.9	

Analysis Notes

num surveys rejected: (0) ZERO Background = (~~0<val<50~~) ~~30-55~~ 80-95 FT

RADIATION DECAY RATE (58-76 FT) SAME GENERAL PROFILE AS C-TP FOR 22-08-12 (BUT WELLS ARE NOT IN PROXIMITY) (SB-125 DECAY LINE INCLUDED TO SHOW THAT RATE OF DECAY DOES NOT FIT) IDENTITY OF OTHER ISOTOPES (IF PRESENT) CAN NOT BE ESTABLISHED

Category: (Stable, TF Activity, Undetermined, CHANGED) ZONE 58-76 FT

Analyst Name Randall Price S/W ver (TFGROSS) V2.20

filein := "two58-76.txt" **Well 22-10-10**

A := READPRN(filein) $yr := A^{\langle 1 \rangle}$ $net := A^{\langle 7 \rangle}$ $bkg := A^{\langle 6 \rangle}$ $max := A^{\langle 4 \rangle}$

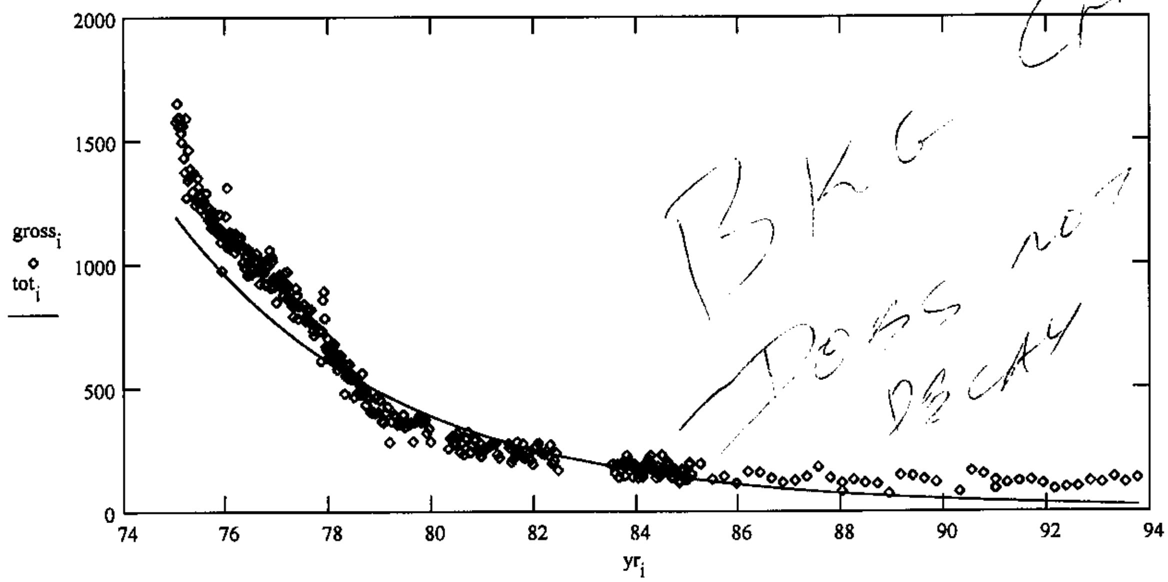
N := last(yr) N = 393 i := 0 .. N k := 0 .. 300 j := 0 .. 299

1st Isotope is Co (5.27 yrs) $\tau co := 5.27$ aco := 200

2nd Isotope is Sb125 (2.77 yrs) $\tau 2 := 2.77$ a2 := 1000

$Co_i := aco \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := a2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$gross_i := net_i$ This data edited for spurious points



BKG CHANGES DOES NOT FIT DECAY

$$ssq(a1,a3) := \sum_i \left[gross_i - \left[a1\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}} + a3\cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}\right]\right]^2$$

THUS RESULTS OF LEAST SQ. FIT ARE INVALID.

Given

ssq(aco, a2)=0 1=1

$$\begin{bmatrix}\alpha co \\ \alpha 2\end{bmatrix} := Minerr(aco, a2)$$

$\alpha co = -65.318$ $\alpha 2 = 1.534 \cdot 10^3$

$\frac{\alpha co}{\alpha 2} = -0.043$

$Co_i := \alpha co \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau co}}$ $X2_i := \alpha 2 \cdot e^{-(yr_i - 75)\cdot\frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$out^{\langle 0 \rangle} := yr$ $out^{\langle 1 \rangle} := tot$ WRITEPRN("twop.txt") := out Ratio Co/Sb $\frac{Co_N}{X2_N} = -0.395$

Borehole 22-11-01

Contamination (Cs-137) from 0-5 and 5-10 feet is TF Activity
Contamination (Cs-137) from 19 to 28 feet is UNSTABLE

Grade Thickness Product from 0 to 5 feet is erratic for the 20 years of survey data and is categorized as Tank Farm activity. Changes in the logging procedure when logging surface radioactive zones perturbs reliable calculation of the Grade Thickness Product. A decay line for Cs-137 (identified from HPGe detector) that was fitted to the last few non-zero survey values is presented.

Grade Thickness Product from 5 to 10 feet is erratic from 1983 to 1986 and is categorized as Tank Farm activity. Grade Thickness Product from 1984 through 1994 is decreasing within counting statistics at a rate consistent with Cs-137 (identified from HPGe detector).

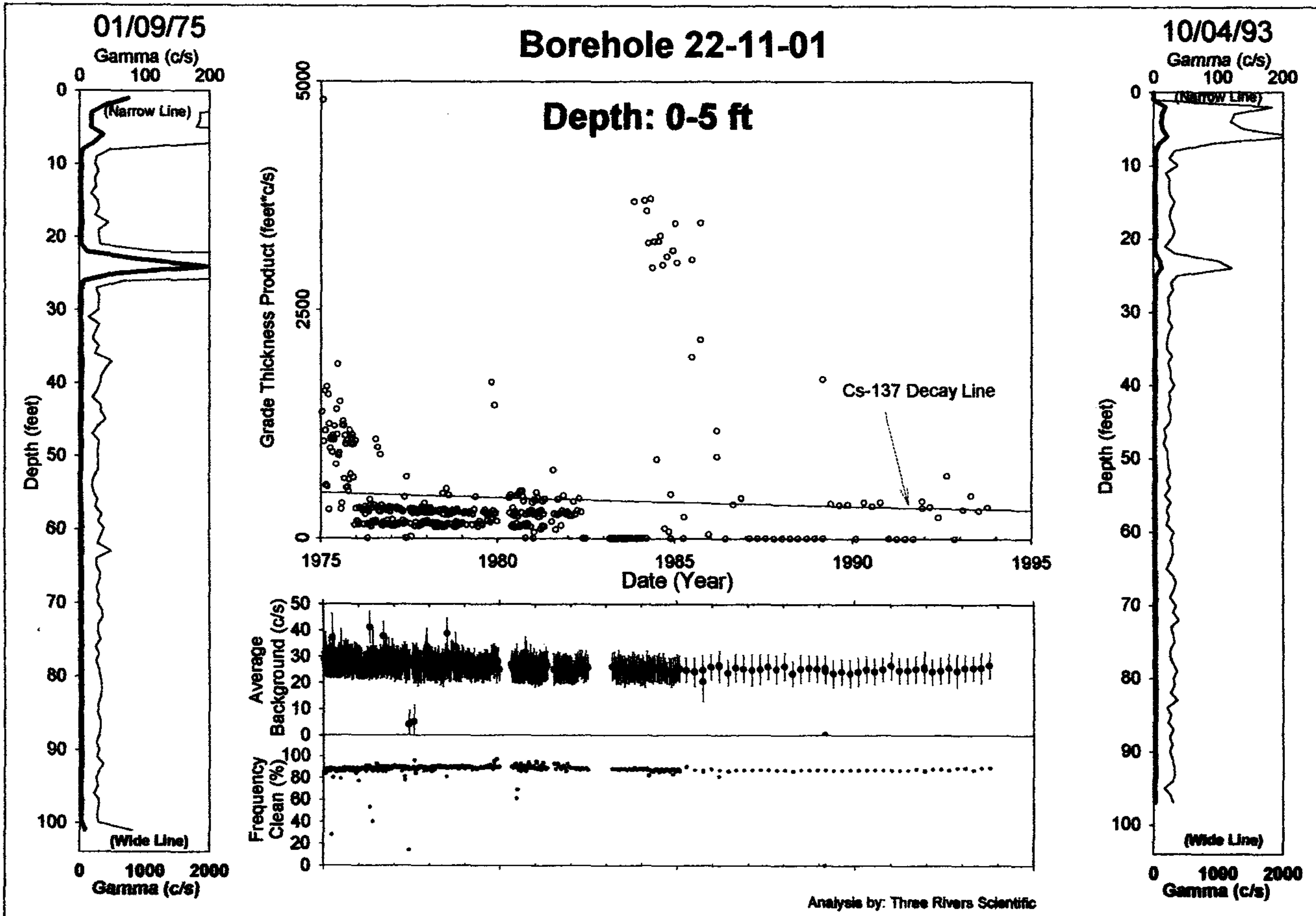
Grade Thickness Product for the radioactive zone (19-28 feet) has four time intervals of changed activity. (1) Grade Thickness Product was decreasing within the gross gamma sensitivity at a rate consistent with Cs-137 (identified from HPGe detector) from 1975 to 1980, then a step change in concentration may have occurred. (2) From 1980 to 1983 the Grade Thickness Product continued to decrease with Cs-137 decay. (3) From 1983 to 1989 the Grade Thickness Product was erratic with five pulses of increased and decreased activity. (4) From 1989 to the end of the surveys (1993) the Grade Thickness Product has decreased dramatically.

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (5 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	10/4/1993
Number Surveys :	415

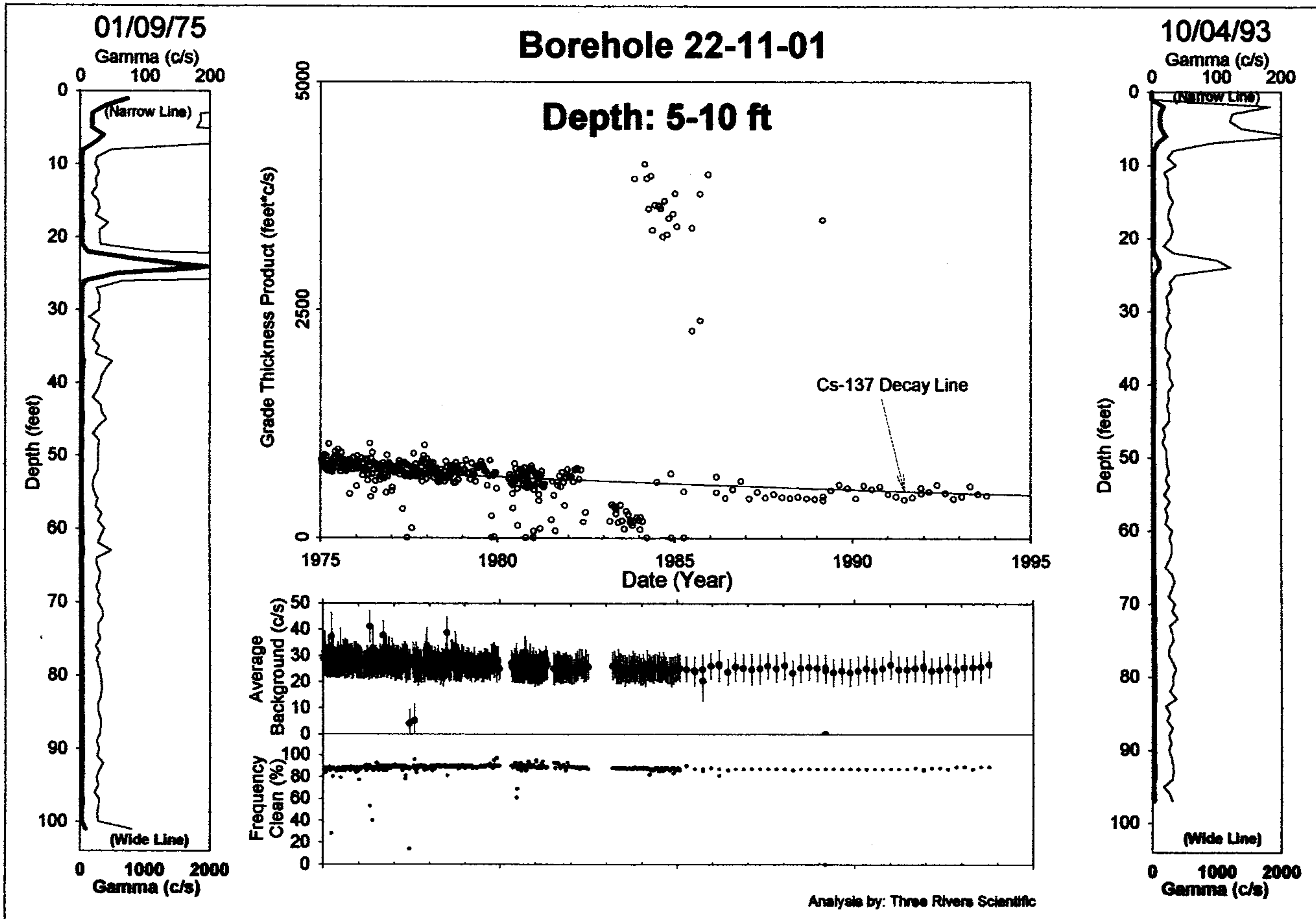
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	Zones 0-10': Threshold (0< val < 50) Zone 19-28': Bkg = 30-45'
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-5, 5-10 feet is TF Activity 19-28 feet is UNSTABLE
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



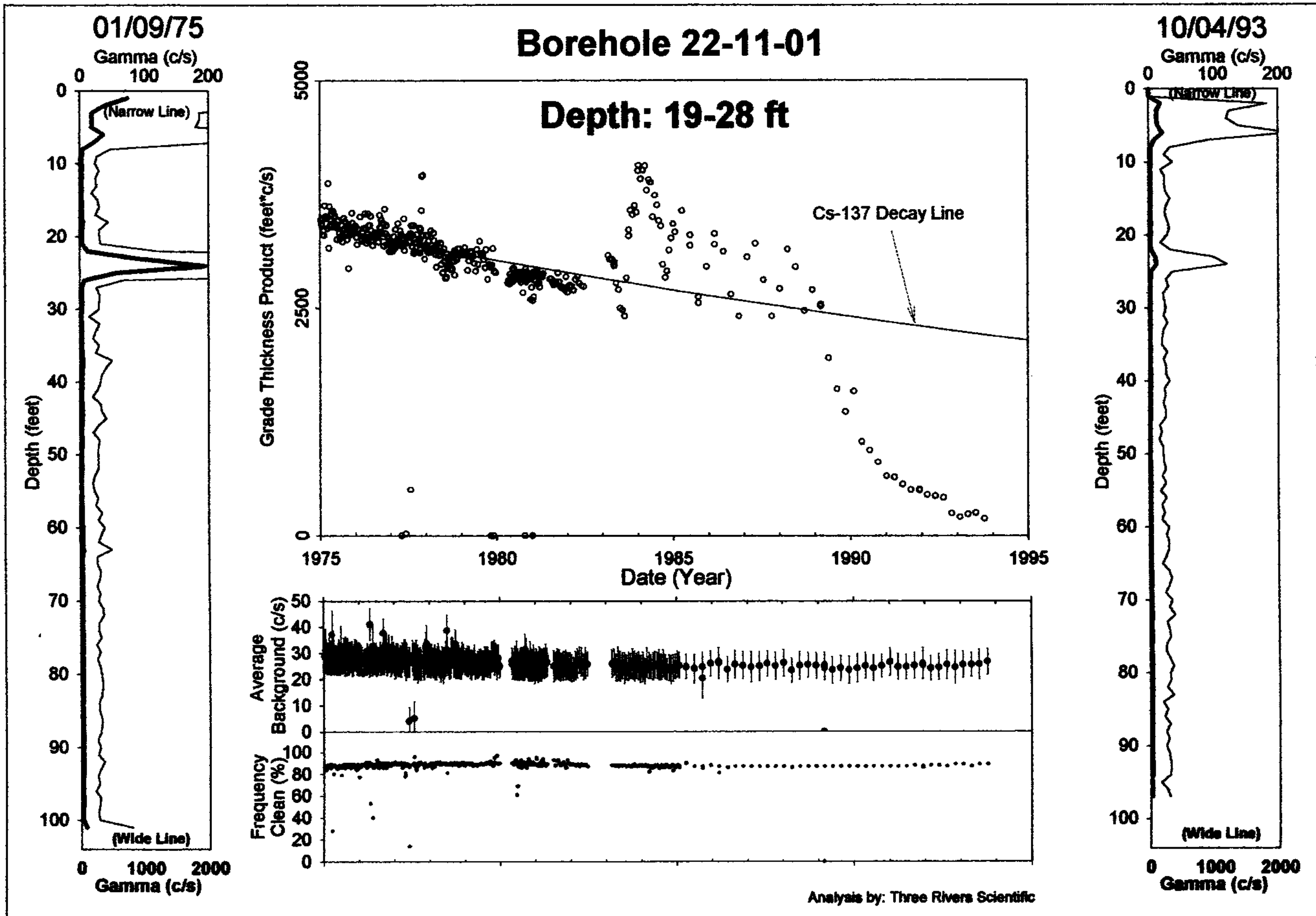
Borehole 22-11-01
Depth: 0-5 ft
01/09/75
Gamma (c/s)
0
100
200
(Narrow Line)
(Wide Line)
0
1000
2000
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
0
2500
5000
Cs-137 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific
10/04/93
Gamma (c/s)
(Narrow Line)
(Wide Line)
Gamma (c/s)
Depth (feet)

00 492



00 493

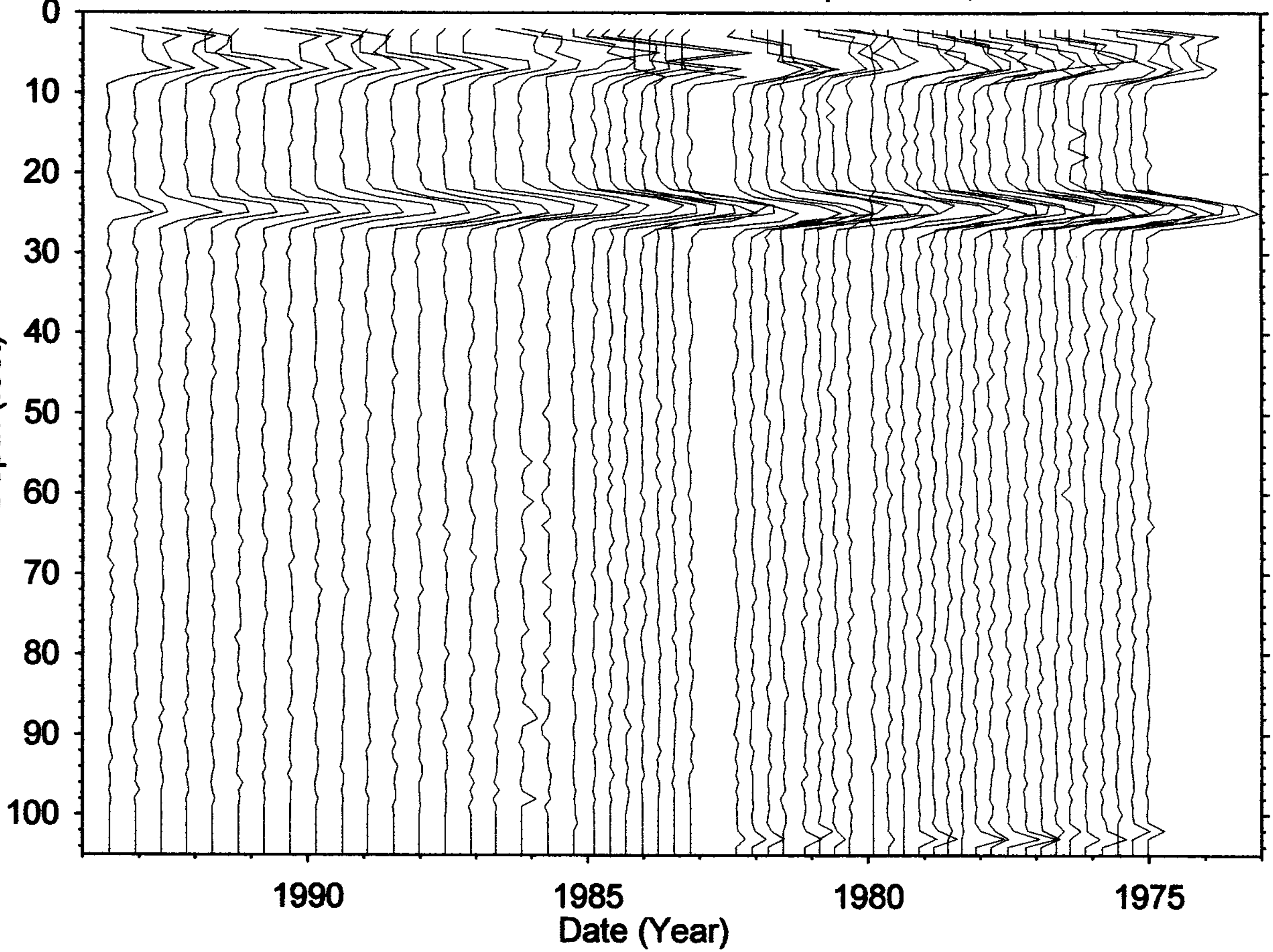
HNF-3532 -REV0



00 494

HNF-3532-REV0

Borehole 22-11-01 Depth Shifted; Reverse Time Scale



Borehole 22-11-05

Contamination (Cs-137) from 0 to 10 feet is TF Activity

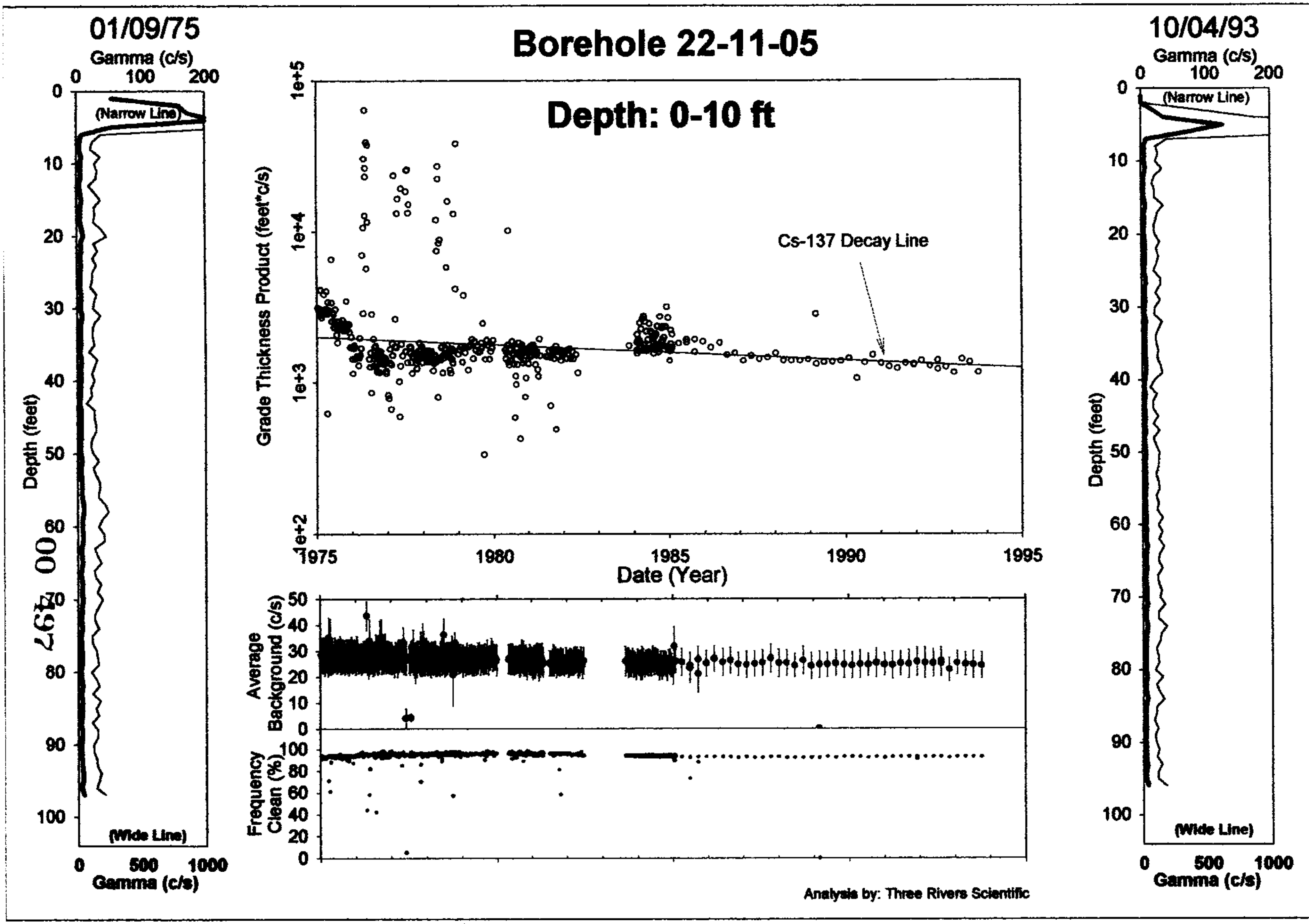
Grade Thickness Product from 0 to 10 feet is erratic from 1975 to 1985 and is categorized as Tank Farm activity. A decay line for Cs-137 (identified from HPGe detector) shows the surveys since 1985 are consistent with the radionuclide decay.

Gross Gamma Survey Information

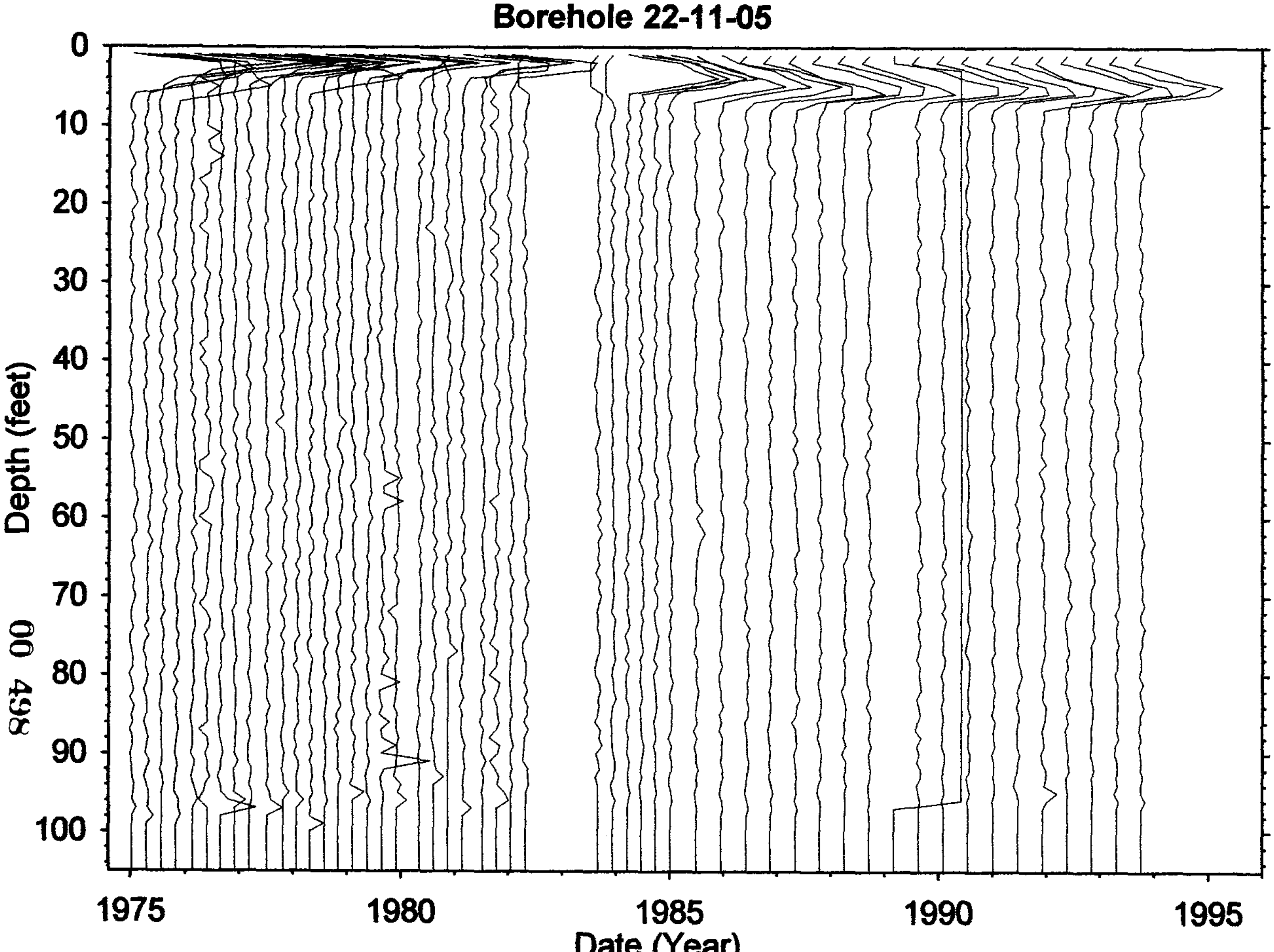
Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (5 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	10/4/1993
Number Surveys :	450

Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	Threshold (0< val < 50)
Depth(s) where Contamination Identified in Gross Gamma Surveys :	**0-10 feet is TF Activity**
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



HNF-3532 -REV0



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HNF-3532-REV0

Borehole 22-11-08

Contamination (Cs-137) from 0 to 10 feet is TF Activity
Contamination (U-238/Pa-234 & Co-60) from 56 to 66 feet is Stable

Grade Thickness Product from 0 to 10 feet is erratic during 1975, 1981, 1984 to 1986, and is categorized as Tank Farm activity. A decay line for Cs-137 (identified from HPGe detector) is shown for reference.

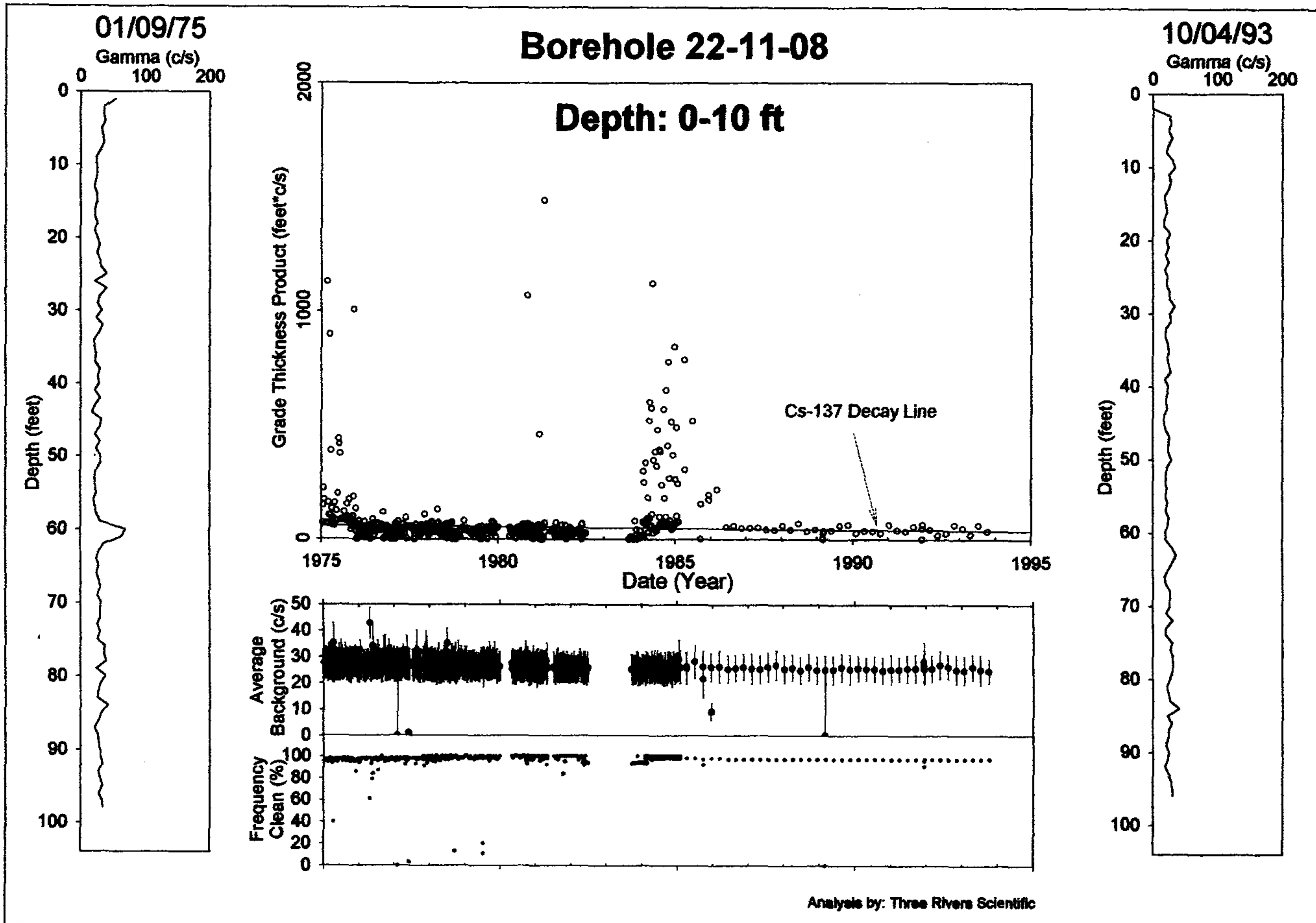
Grade Thickness Product for the radioactive zone (56-66 feet) is decreasing within the gross gamma sensitivity to each isotope and relative intensity at a rate consistent with a least squares fit of Co-60 (hypothesis) and U-238/Pa-234 (identified from HPGe detector) between January 1979 and October 1994. Protactinium (Pa-234) is a decay product of U-238. The least squares fit results in a gross gamma contribution ratio for Co-60 to U-238/Pa-234 of 0.5 on October 1994.

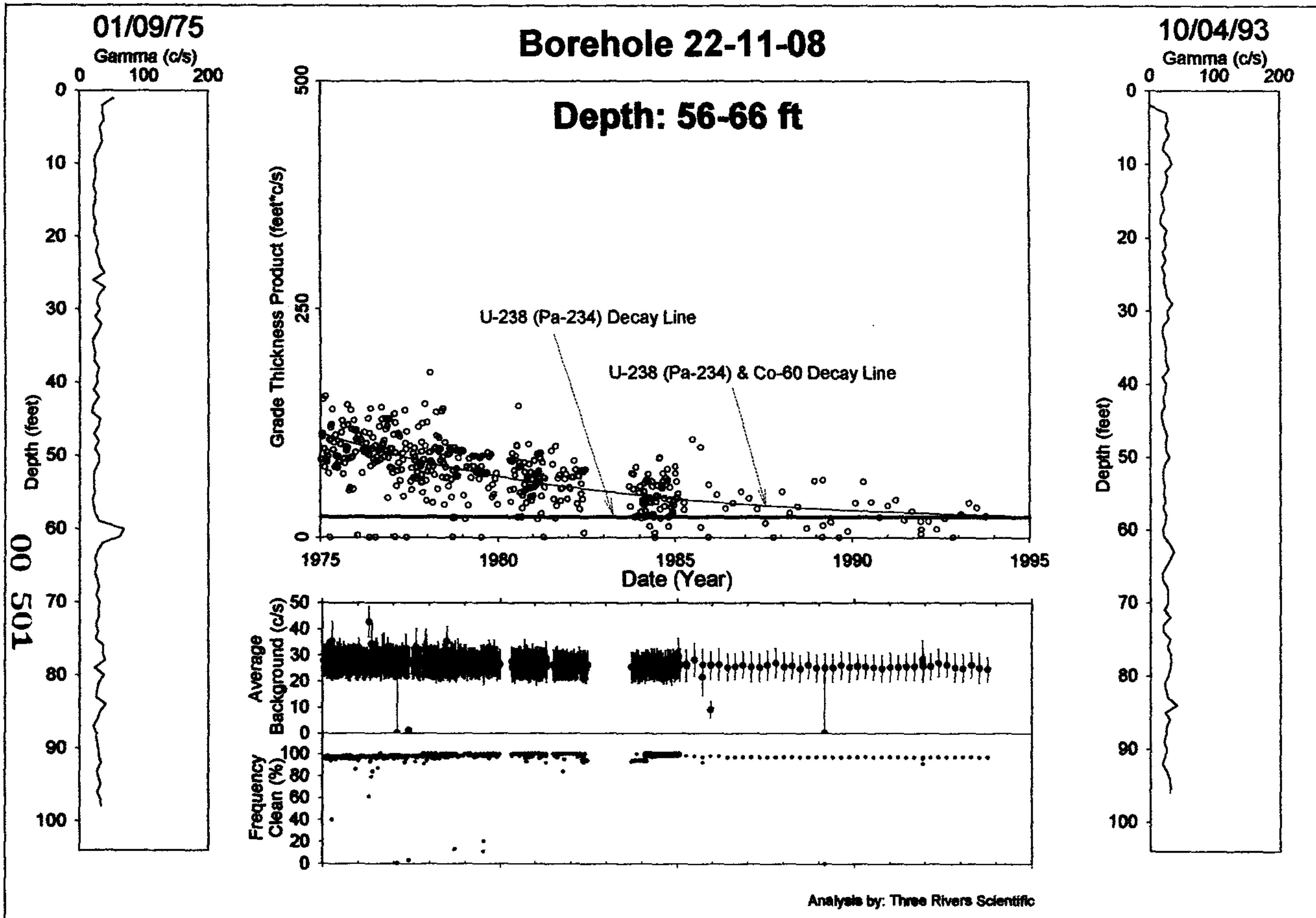
Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (5 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	10/4/1993
Number Surveys :	438

Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	40 to 50 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	**0-10 feet is TF Activity** **56-66 feet is Stable**
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific

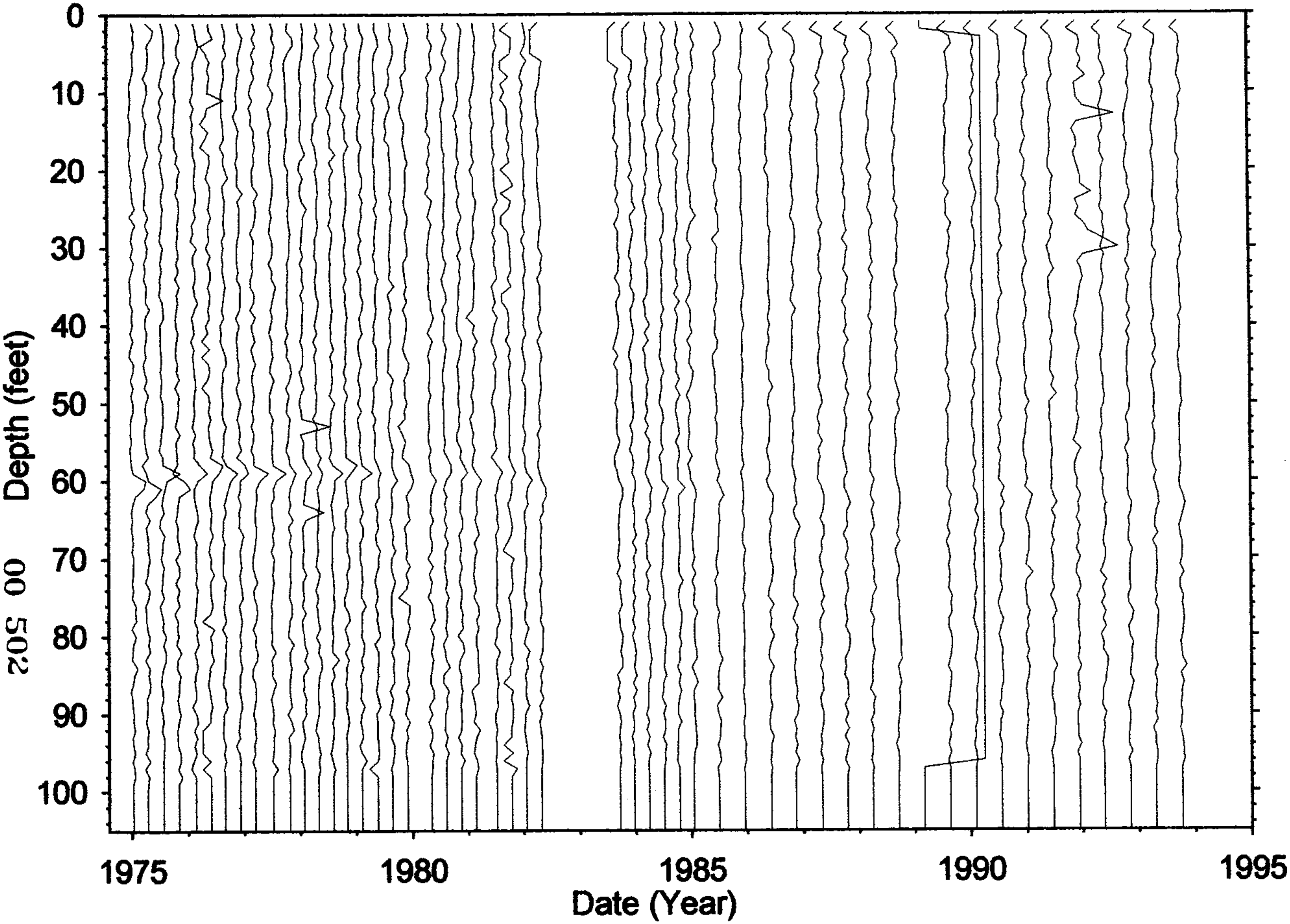

Borehole 22-11-08
Depth: 0-10 ft
01/09/75
Gamma (c/s)
Depth (feet)
10/04/93
Gamma (c/s)
Depth (feet)
Grade Thickness Product (feet*c/s)
Cs-137 Decay Line
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific



HNF-3532 -REV0

00 501

Borehole 22-11-08



HNF-3532 -REV0

Borehole 22-11-09

Contamination (Cs-137) from 0 to 8 feet is TF Activity
Contamination (Co-60) from 20 to 34 feet is Stable
Contamination (Co-60) from 34 to 46 feet was UNSTABLE early

Grade Thickness Product from 0 to 8 feet is erratic for the 20 years of survey data and is categorized as Tank Farm activity. A decay line for Cs-137 (identified from HPGe detector) is shown for reference and was fitted to the last few years of survey data.

Grade Thickness Product for the radioactive zone (20-34 feet) is decreasing within observed systematic limitations at a rate consistent with the decay of Co-60 (identified from HPGe detector) between 1975 and 1994.

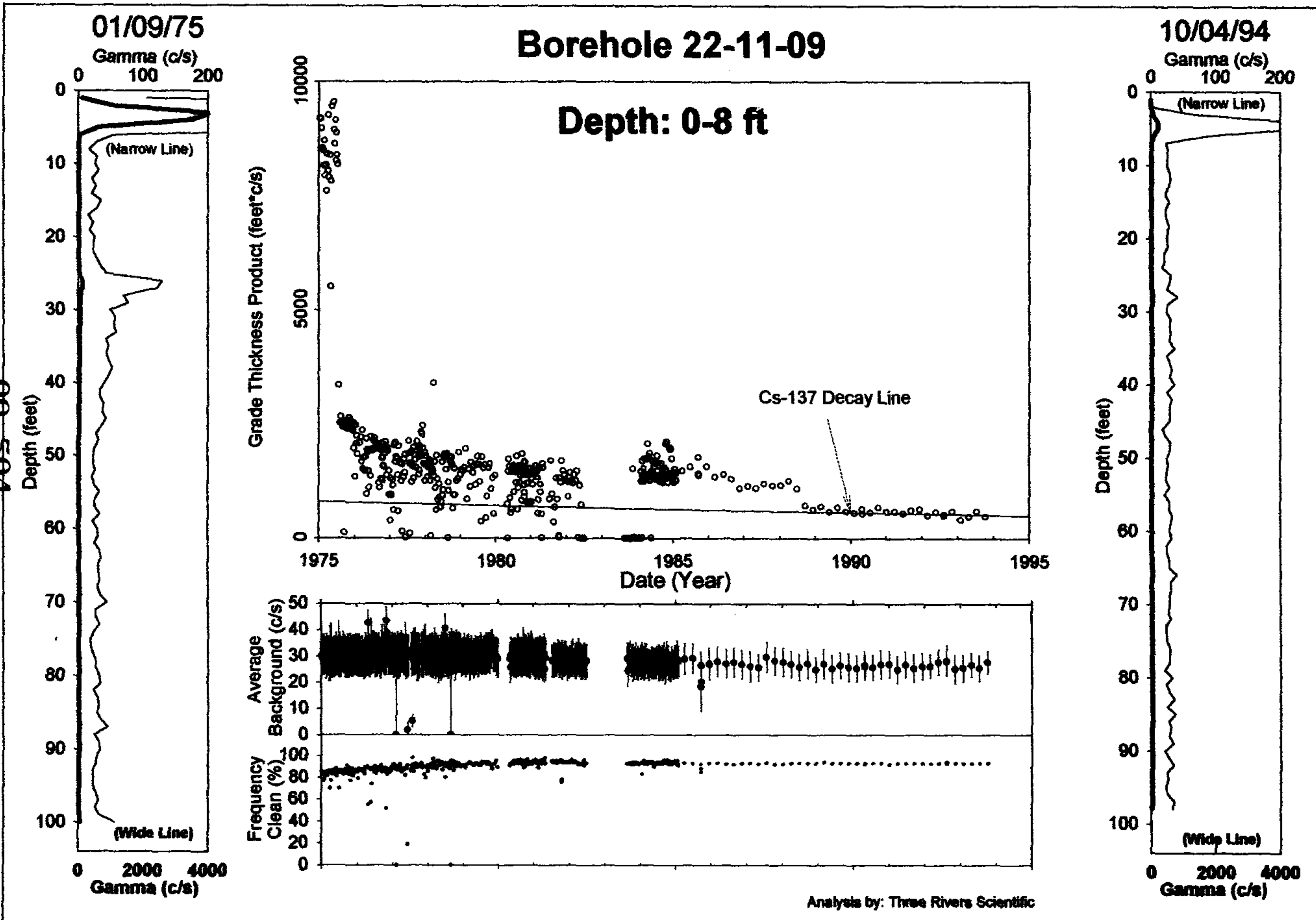
Grade Thickness Product for the radioactive zone (34-46 feet) from 1975 to 1978 was not showing radioactive decay and is classified as UNSTABLE. Then from 1978 to 1994 the radiation zone is decreasing within observed systematic limitations at a rate consistent with the decay of Co-60 (identified from HPGe detector.)

Gross Gamma Survey Information

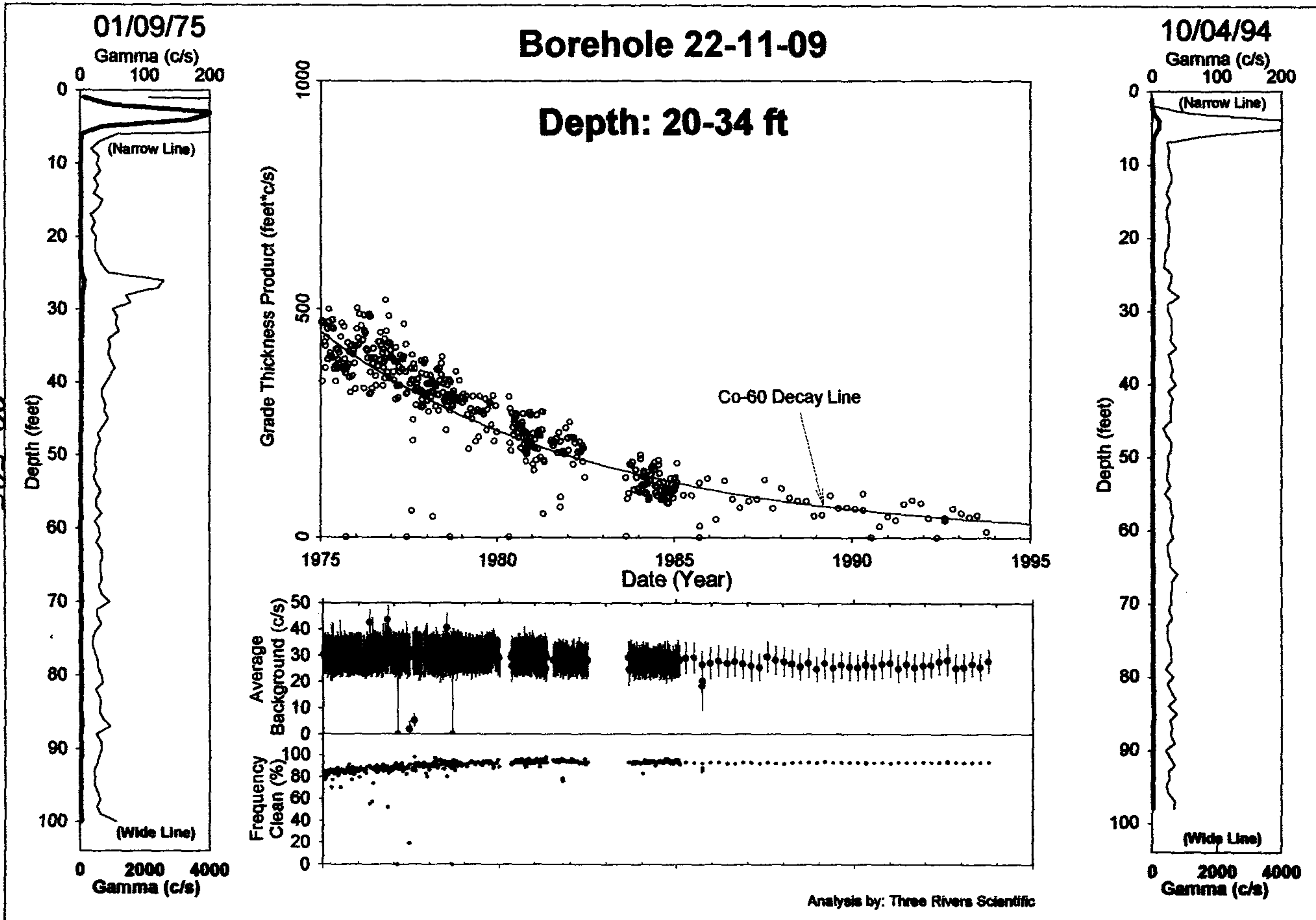
Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (4 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	10/4/1993
Number Surveys :	437

Analysis Notes

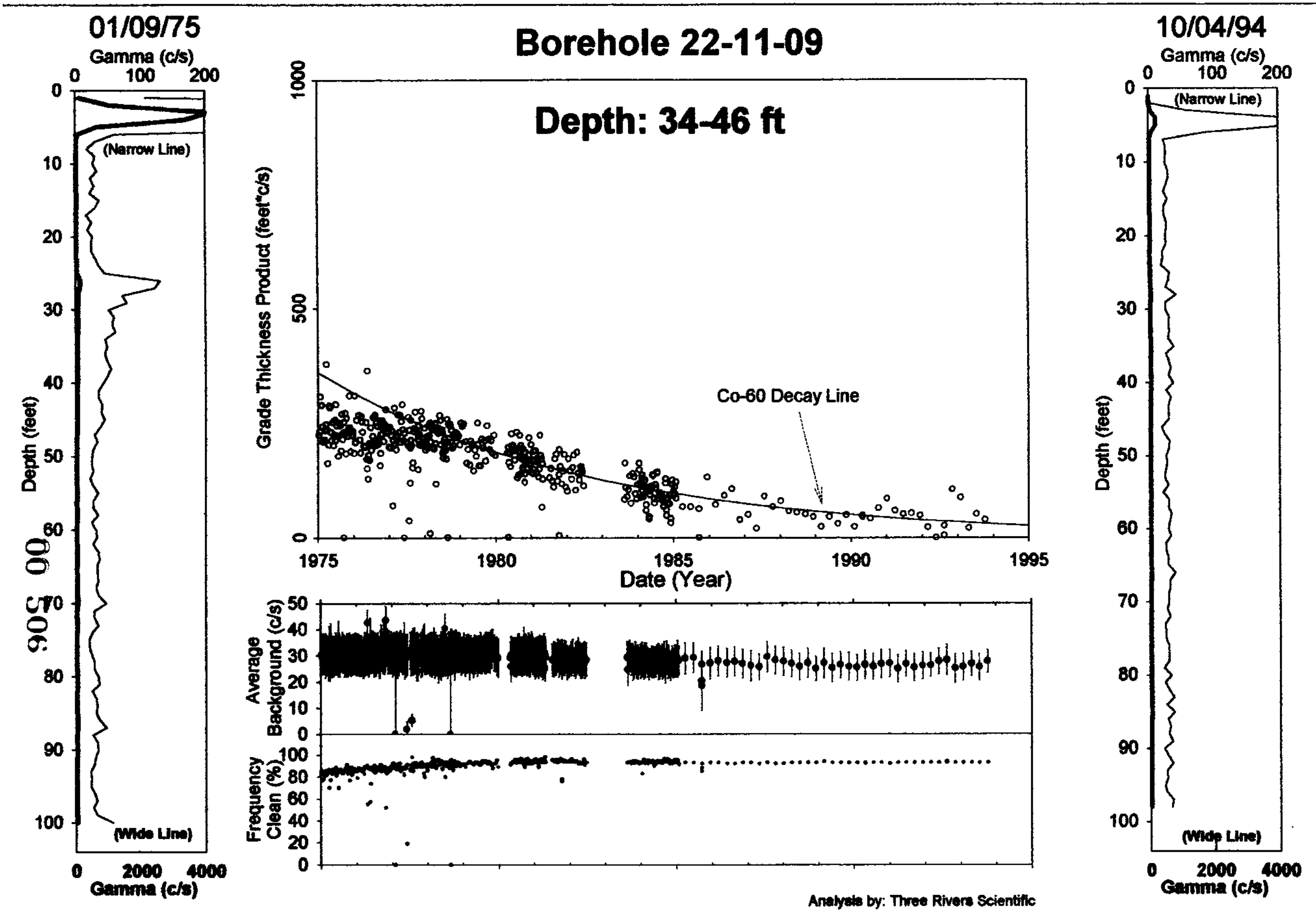
Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	10 to 20 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-8 feet is TF Activity 20-34 feet is Stable 34-46 feet was UNSTABLE early
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



HNF-3532 -REV0

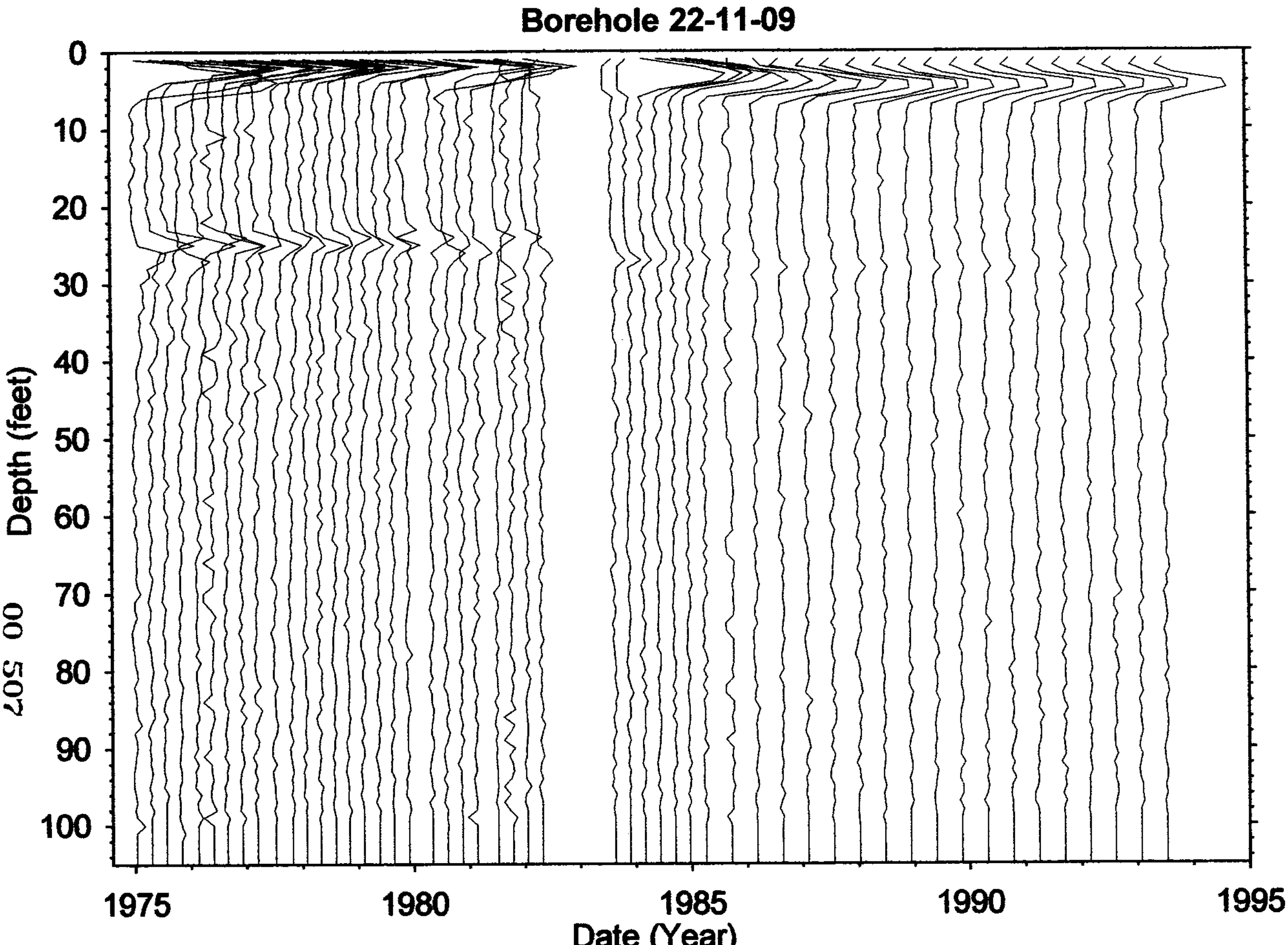


Borehole 22-11-09
Depth: 20-34 ft
01/09/75
10/04/94
Gamma (c/s)
0
100
200
(Narrow Line)
(Wide Line)
Depth (feet)
0
2000
4000
Grade Thickness Product (feet*c/s)
Co-60 Decay Line
1975
1980
1985
1990
1995
Date (Year)
Average Background (c/s)
Frequency Clean (%)
Analysis by: Three Rivers Scientific



00 506

HNF-3532 -REV0



HNF-3532 -REV0

00 507

Dry Well Survey Analysis - Notes

Borehole BY(22-11-01) Total # Surveys 419 Probe Type 04

neutron surveys 5 # GR Surveys 415

Log Date: 75-01-09 1st 93-10-04 Last Presentation Plot Dates ______ (If different from 1st & Last)

Isotope from Spectral Survey: CS-137 < 100 p Ci/g (0-8 FT) Max Survey Depth 100'

Contamination Zone Depth(s): 0-5 FT, 5-10, 19-28

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
75-12-31	12	100	
77-06-02	86	100	
84-03-16	12	100	
84-11-21	12	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-03-26	TOOL NOISE	100	
76-05-20A	TOOL NOISE	100	
77-04-21A	NO RAD ZONES	100	
79-10-31	NO RAD ZONES	100	
80-06-19	TOOL NOISE	95	
89-03-01	BAD SURVEY	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-03-26	AVG BKG	101	28%	37.1	
76-04-22	%CLEAN	98	53%	41.1	
76-09-09	AVG BKG	99	88%	32.7	
77-06-02	%CLEAN	101	14%	42.0	
77-07-22	AVG BKG	98	96%	5.3	
78-06-28	AVG BKG	99	81%	38.8	
80-06-19	%CLEAN	95	61%	7.0	
89-03-01	%CLEAN	98	0%	0.0	

Analysis Notes

num surveys rejected: (0) ZERO Background = ~~(0<val<50)~~ 30-45 FT 19-28 FT ZONE
RADIATION ZONE (3) 0-5, 5-10, 19-28) 0<VAL<50 (0-595-10 FT)
DEPTH SHIFTED ON TRAIL EDGE OF 8 FT PEAK
0-5, 5-10 TF ACTIVITY
19-28 (CHANGING)
Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Kurtz S/W ver (TFGROSS) V 2.20.

Dry Well Survey Analysis - Notes

Borehole BY(22-11-05) Total # Surveys 455 Probe Type 04
neutron surveys 5 # GR Surveys 450
Log Date: 75-01-09 1st 93-10-04 Last Presentation Plot Dates
(If different from 1st & Last)
Isotope from Spectral Survey: CS-137 (<100 pCi/g 2-8 FT) Max Survey Depth 100
Contamination Zone Depth(s):

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-07-28	47	90	
77-06-02	91	100	
78-09-27	40	100	
81-10-27	33	80	
85-06-28	26	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-01-09	HI-BKG	100	
76-05-20	HI-BKG	100	
76-07-28	NORAD Zone	100	
77-10-31	HI-BKG	100	
81-10-27	NORAD ZONE	80	
89-03-01	RAD Zone	100	BAD SURVEY

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-07-31	LENGTH	190	93%	27.6	
76-04-22	AVG BKG	95	44%	43.5	
76-08-27	LENGTH	185	96%	28.9	
77-06-02	% CLEAN	96	5%	4.0	
77-07-22	AVG BKG	95	97%	4.2	
78-06-28	AVG BKG	96	95%	36.2	
78-09-27	% CLEAN	96	57%	20.8	
81-10-27	% CLEAN	80	58%	25.6	
89-03-01	% CLEAN	96	0%	0.0	

Analysis Notes

num surveys rejected: (0) ZERO Background = (0<val<50)

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name ______ S/W ver (TFGROSS)______.

Dry Well Survey Analysis - Notes

Borehole B4 (22-11-08) Total # Surveys 443 Probe Type 04
neutron surveys 5 # GR Surveys 438
Log Date: 75-01-09 1st 93-10-04 Last Presentation Plot Dates ______
(If different from 1st & Last)
Isotope from Spectral Survey: CS-137 (<8 pCi/g 0-10) PA 62' Max Survey Depth 100
Contamination Zone Depth(s): ______

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
77-06-02	93	100	
79-07-11A,B	184	170	
81-10-13	15	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-04-09	HI-BKG	100	
76-05-05	HI CPS/0FT	170	
77-02-03	HI-BKG	102	
78-09-14A	BAD SURVEY	100	
89-03-01	BAD SURVEY	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
76-04-22	AVG BKG	95	61%	42.8	
76-07-21	LENGTH	202	87%	28.2	
77-02-03	%CLEAN	98	0%	0.0	
78-09-14	%CLEAN	97	13%	25.4	
79-07-11	B SURVEY	230	20%	23.8	
85-12-12	AVG BKG	97	98%	9.0	
89-03-01	%CLEAN	96	0%	0.0	

Analysis Notes

num surveys rejected: (0) ZERO Background = (0<val<50) 65 ~~70 95~~ 40-50FT
ZONE 56-64
ZONE 0-10 BKG 15-40
* SUSPECT (56-64FT) ANOTHER SHORT LIVED ISOTOPE (Sb, Co, Eu)
BUT SINCE NONE IDENTIFIED BY HPGE, WILL NOT PRESENT
UNTIL OTHER INPUT RECEIVED
REVIEW W/ NEW BKG CALC (40-50FT) FOR ZONE 56-64: FIT W/ Co & U.
Category: (Stable, TF Activity, Undetermined), CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V2.20.

filein := "GTP56-66.txt" **Well 22-11-08**

$A := \mathrm{READPRN}(\mathrm{filein})$ $yr := A^{\langle 1 \rangle}$ $net := A^{\langle 7 \rangle}$ $bkg := A^{\langle 6 \rangle}$ $max := A^{\langle 4 \rangle}$

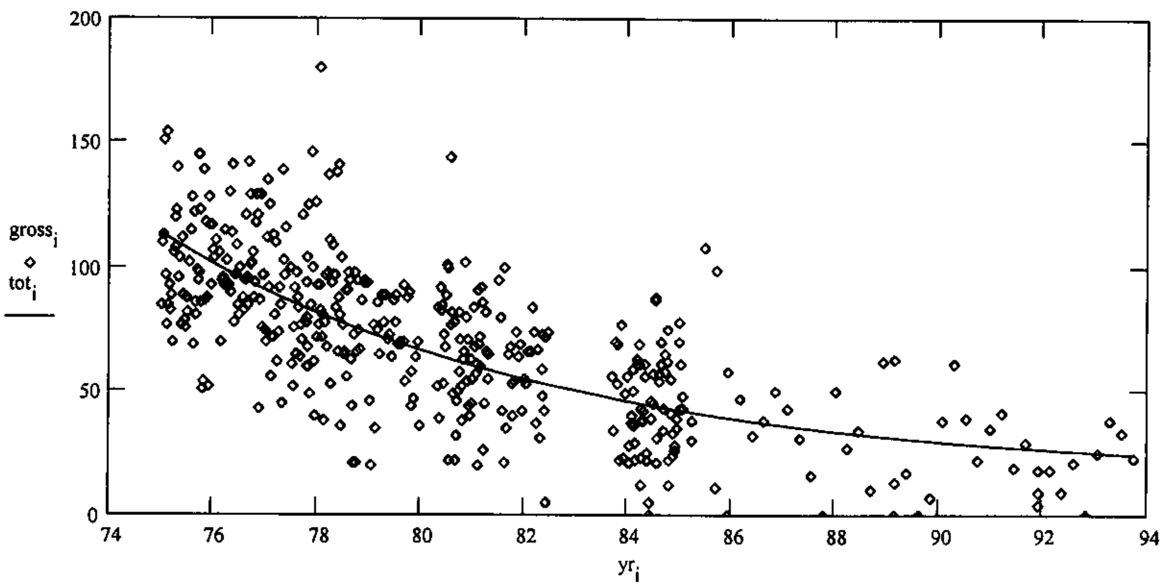
$N := \mathrm{last}(yr)$ $N = 426$ $i := 0..N$ $k := 0..300$ $j := 0..299$

1st Isotope is Co (5.27 yrs) $\tau co := 5.27$ $aco := 98$

2nd Isotope is U (4.5 e9 yrs) $\tau 2 := 4.5 \cdot 10^{9}$ $a2 := 16$

$Co_i := aco \cdot e^{-(yr_i - 75) \cdot \frac{\ln(2)}{\tau co}}$ $X2_i := a2 \cdot e^{-(yr_i - 75) \cdot \frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$gross_i := net_i$ This data edited for spurious points



$$ssq(a1, a3) := \sum_i \left[gross_i - \left[a1 \cdot e^{-(yr_i - 75) \cdot \frac{\ln(2)}{\tau co}} + a3 \cdot e^{-(yr_i - 75) \cdot \frac{\ln(2)}{\tau 2}} \right] \right]^2$$

Given

$ssq(aco, a2) = 0$ $1 = 1$

$$\begin{bmatrix} \alpha co \\ \alpha 2 \end{bmatrix} := \mathrm{Minerr}(aco, a2)$$

$\alpha co = 98.175$ $\alpha 2 = 16.748$

Co-60 Uranium

$\frac{\alpha co}{\alpha 2} = 5.862$

$Co_i := \alpha co \cdot e^{-(yr_i - 75) \cdot \frac{\ln(2)}{\tau co}}$ $X2_i := \alpha 2 \cdot e^{-(yr_i - 75) \cdot \frac{\ln(2)}{\tau 2}}$ $tot_i := Co_i + X2_i$

$out^{\langle 0 \rangle} := yr$ $out^{\langle 1 \rangle} := tot$ WRITEPRN("twop.txt") := out Ratio Co/U $\frac{Co_N}{X2_N} = 0.497$

Dry Well Survey Analysis - Notes

Borehole BY(22-11-09)   Total # Surveys 441   Probe Type 04

\# neutron surveys 4   # GR Surveys 437

Log Date: 75-01-09 1st   93-10-04 Last   Presentation Plot Dates ______ (If different from 1st & Last)

Isotope from Spectral Survey: ______   Max Survey Depth 100

Contamination Zone Depth(s): 0-8', 22-30', 30-44

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
77-08-02	79	100	
81-10-13	20	100	
84-01-16	15	100	
85-09-19	10	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-09-18A	TRUNCATED SCRUB	80	81-04-22: 115' - No Rad Zone
76-05-20A	NOISE		82-06-02 TO 84-02-15 = No Rad
77-06-02	No Rad Zone	100	
77-07-22	No Rad Zone	98	
78-08-23	TOOL FAIL	100	
80-05-06	WRONG HOLE		

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
76-04-22	AVG BKG	98	55%	42.5	
76-05-20	% CLEAN	96	57%	35.3	
76-10-27	AVG BKG	98	52%	43.5	
77-02-03	AVG BKG	98	0%	0.0	
77-06-02	AVG BKG	98	19%	1.9	
78-06-28	AVG BKG	98	80%	40.6	
78-08-23	% CLEAN	99	0%	0.0	
85-09-18	AVG BKG	99	88%	18.4	

Analysis Notes

num surveys rejected: (0) ZERO   Background = ~~(0<val<50)~~ ~~45-95~~ 10-20

RADIATION ZONES (20-34' & 34-46 FT)

20-34' - STABLE 60-60

34-46' - LOW LEVEL - BUT SHOWS INDICATIONS OF MIGRATION FROM FORMATION INTO THIS ZONE (UNDETERMINED)

0-8FT - TF ACTIVITY

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price   S/W ver (TFGROSS) V2.20

Borehole 22-12-01

No Gamma-Ray Emitting Contamination was identified

No significant levels of gamma-ray contamination is present above the survey probe detection threshold between 1975 and 1995 in the vadose zone from 2 to 100 feet.

Surveillance logging activities were not designed to monitor low contamination levels near the surface or bottom of the borehole. Low levels of Cesium-137 (identified from HPGe detector) present at/near the surface and at the bottom were are below the detection threshold as shown on the Grade Thickness Product plots for 0 to 25 and 90 to 105 feet.

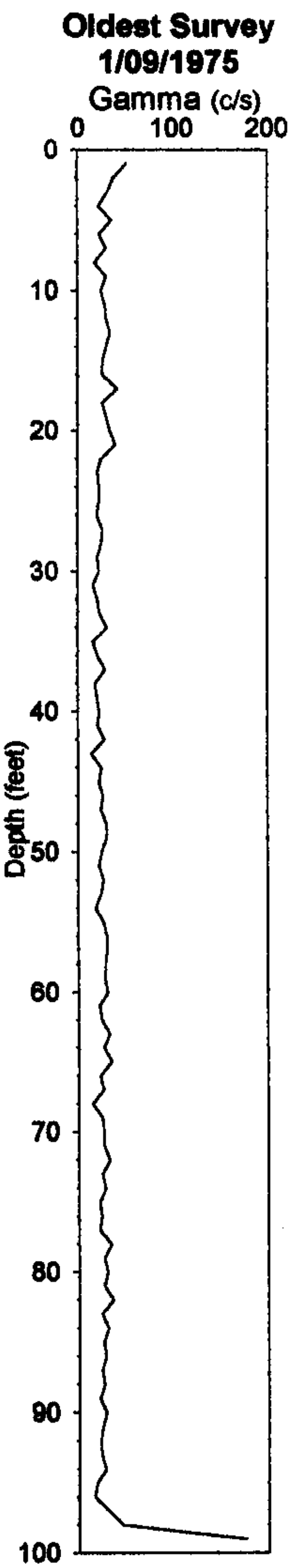
Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (4 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	6/13/1994
Number Surveys :	424

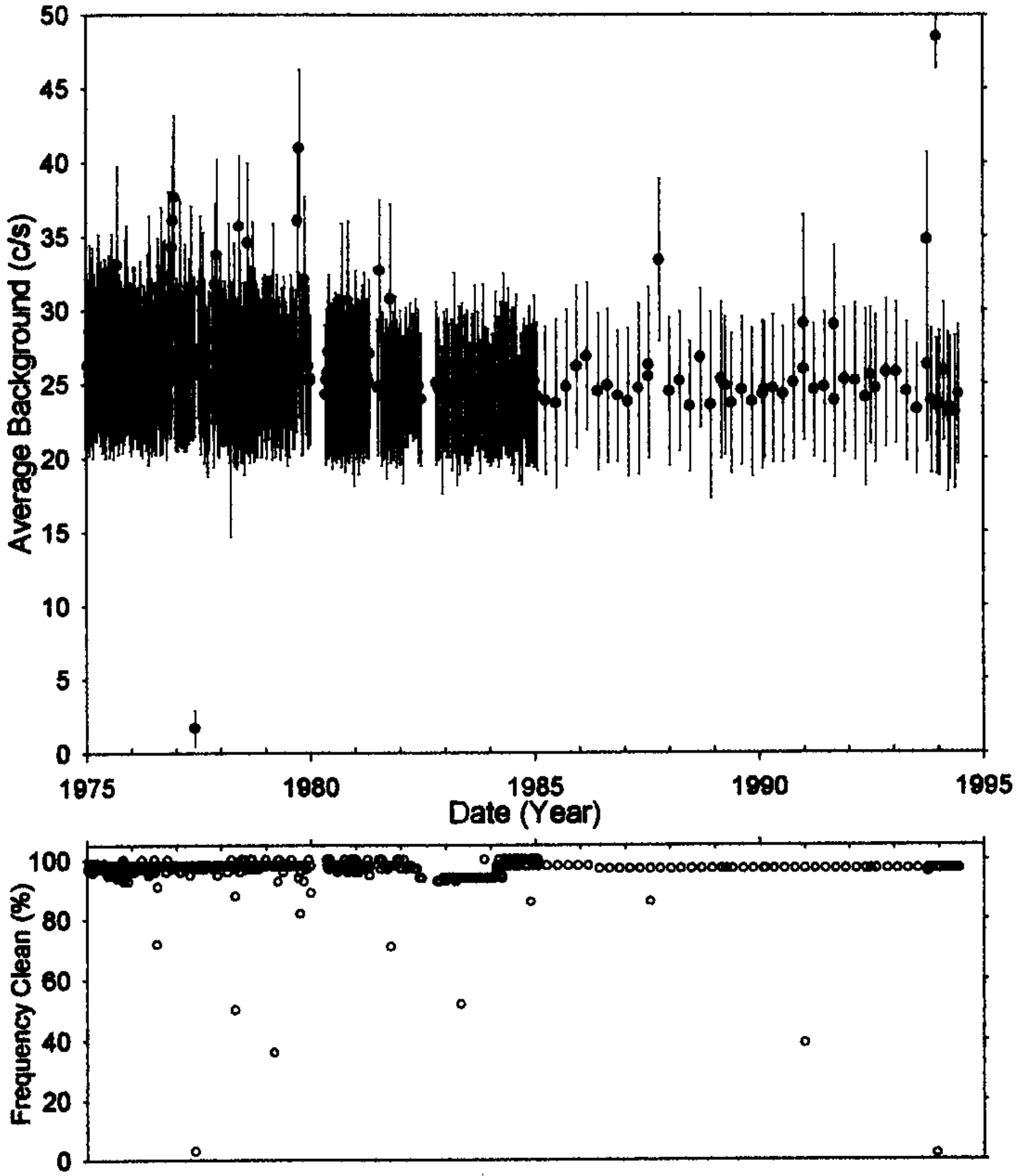
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	Threshold (0< val < 50)
Depth(s) where Contamination Identified in Gross Gamma Surveys :	**No Contamination**
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific

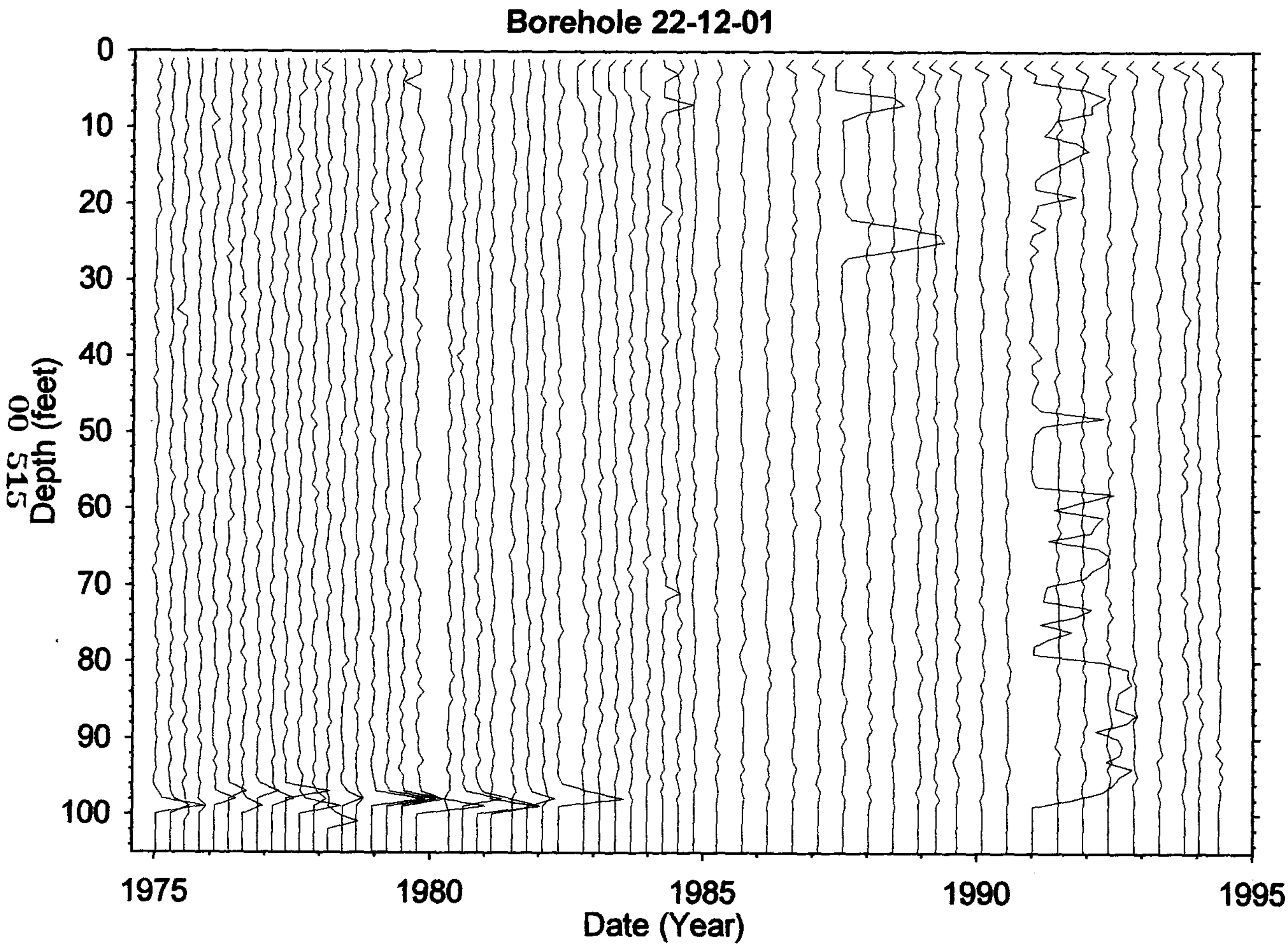
Borehole 22-12-01



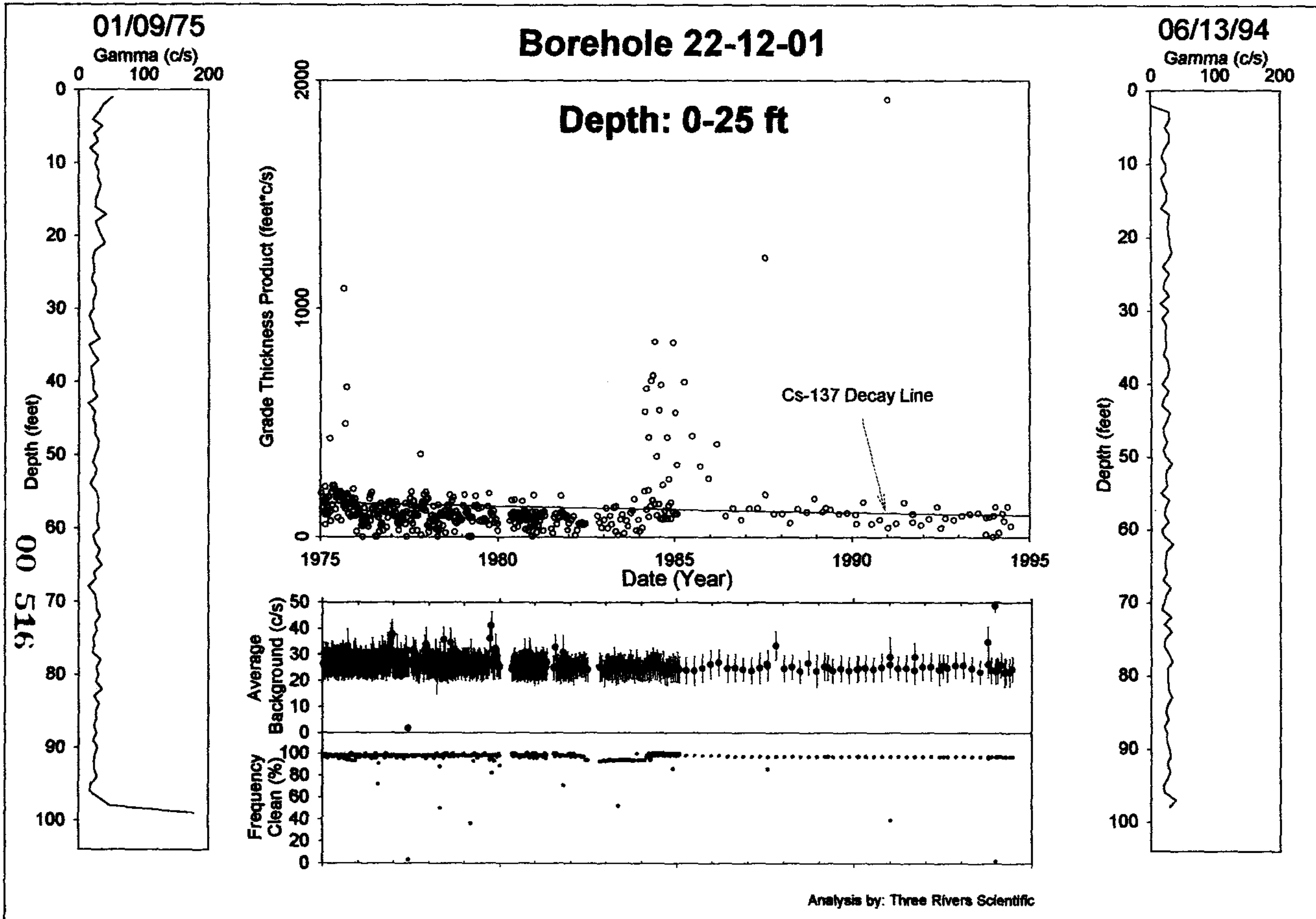
No Gamma-Ray Emitting Contamination Above Survey Detection Threshold



Analysis by: Three Rivers Scientific



HNF-3532 -REV0



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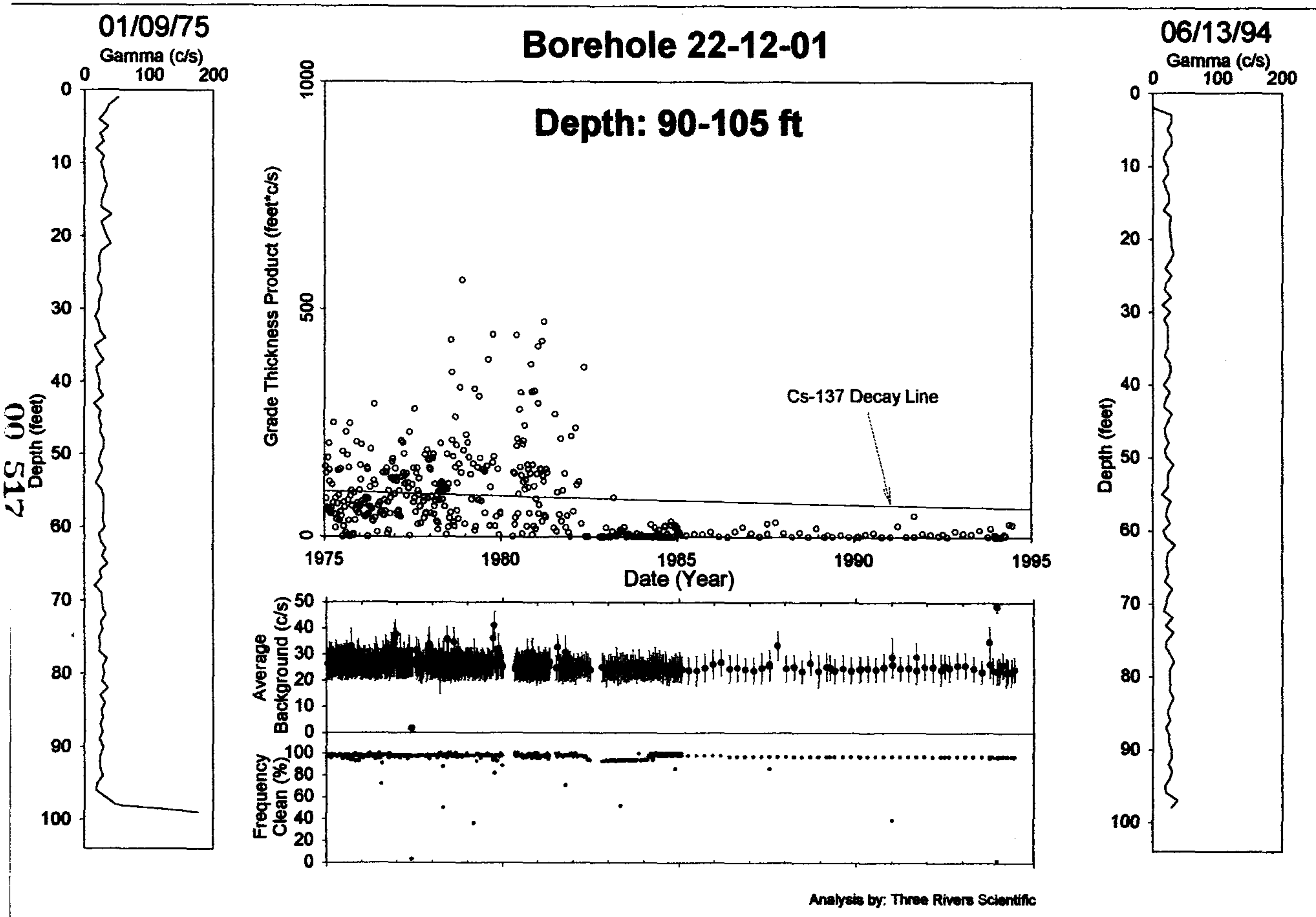
HNF-3532 -REV0



00 517

HNF-3532 -REV0

Borehole 22-12-03

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity
Contamination (Cs-137) from 10-20 feet is Stable

Grade Thickness Product from 0 to 10 feet is erratic for the 20 years of surveillance monitoring, and is categorized as Tank Farm activity. The gross gamma activity exceeds 30,000 counts per second which may be beyond the linear region of the counting system. The decay line for Cs-137 (identified from HPGe detector) approximately agrees with the decrease in Grade Thickness Product.

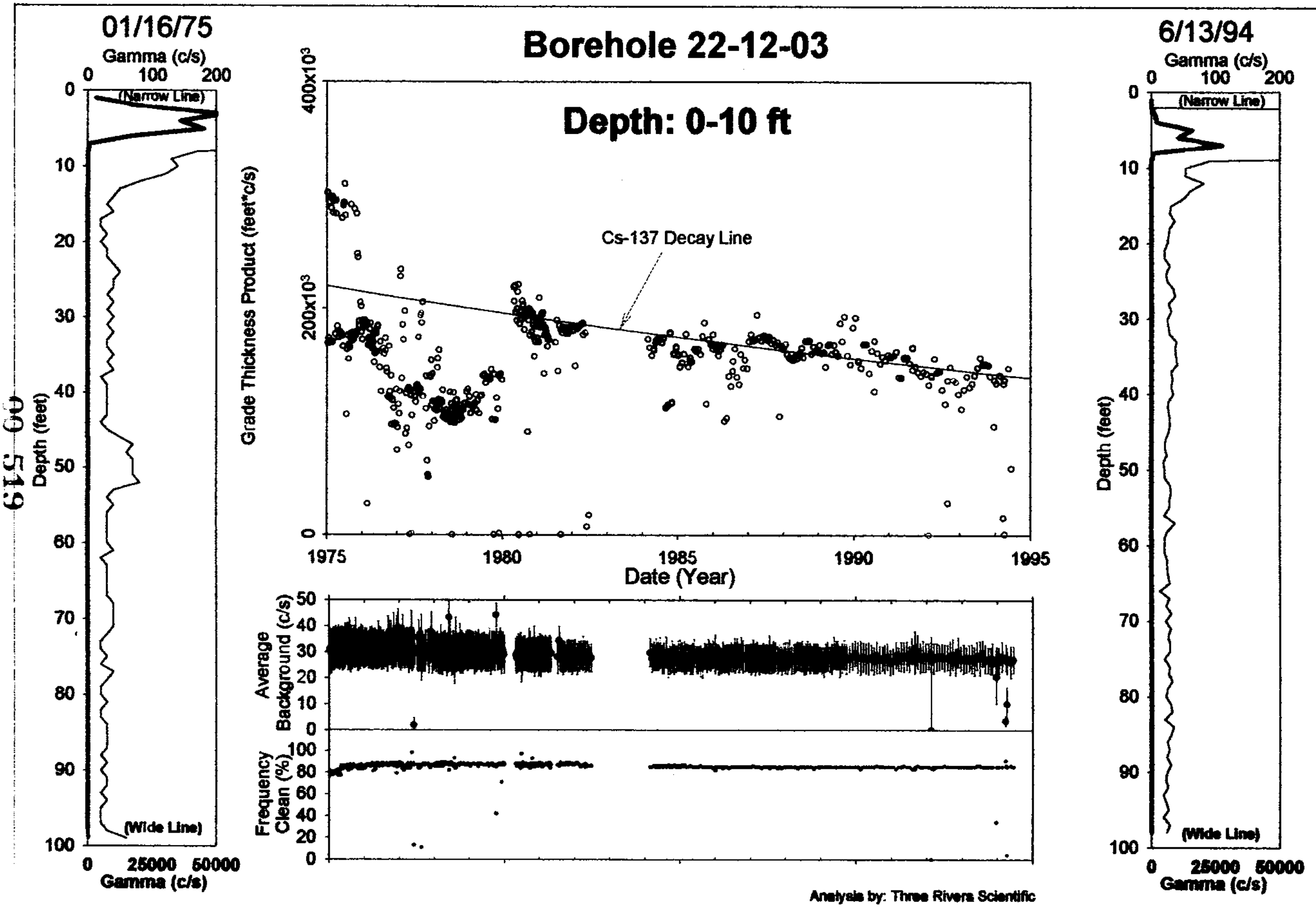
Grade Thickness Product for the radioactive zone (10-20 feet) is decreasing within the gross gamma sensitivity at a rate consistent with the decay of Cesium-137 (identified from HPGe detector) between 1975 and 1994.

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (3 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/10/1975
Last Survey Date :	6/13/1994
Number Surveys :	509

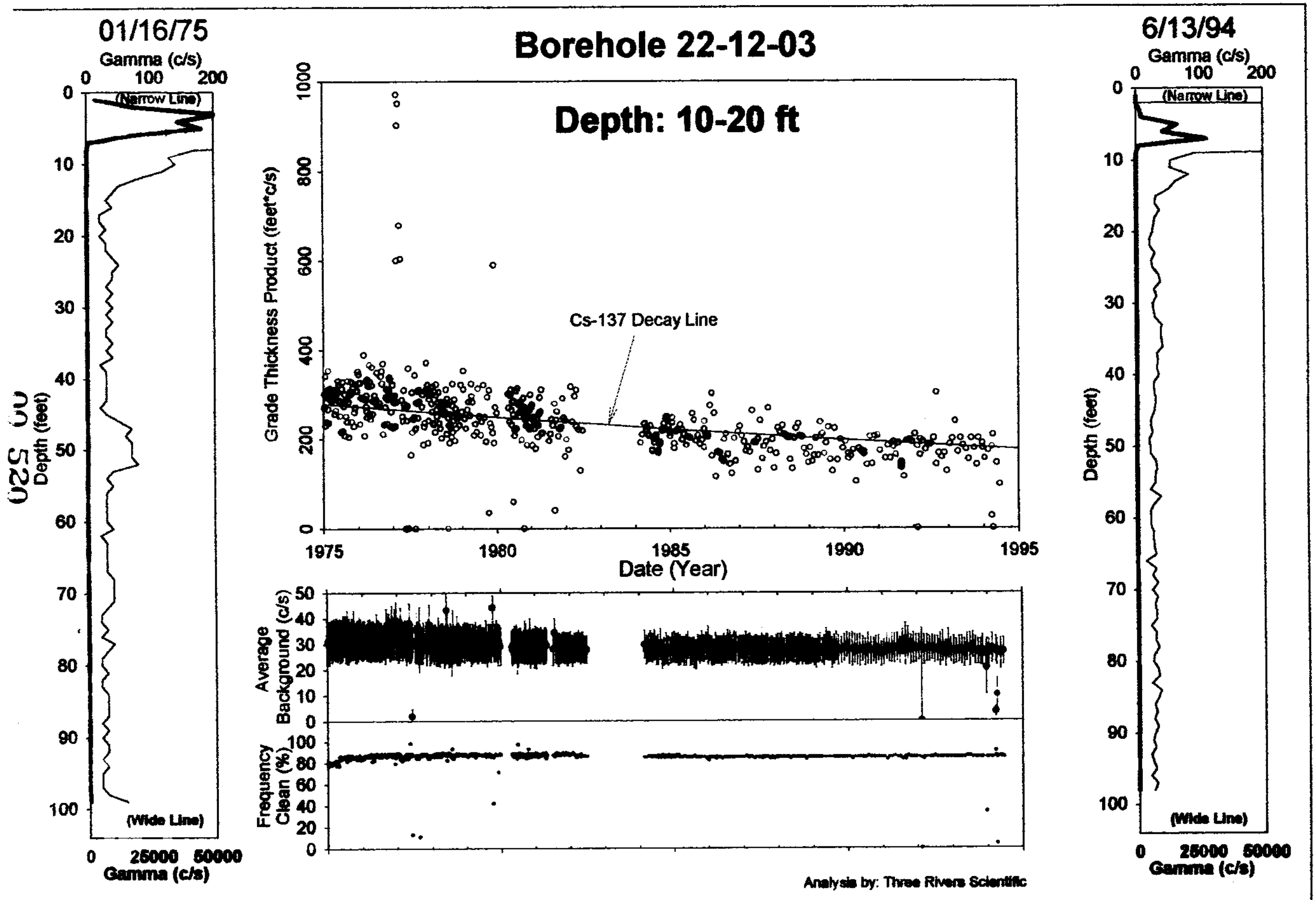
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	28 to 42 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 feet is TF Activity 10-20 feet is Stable
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



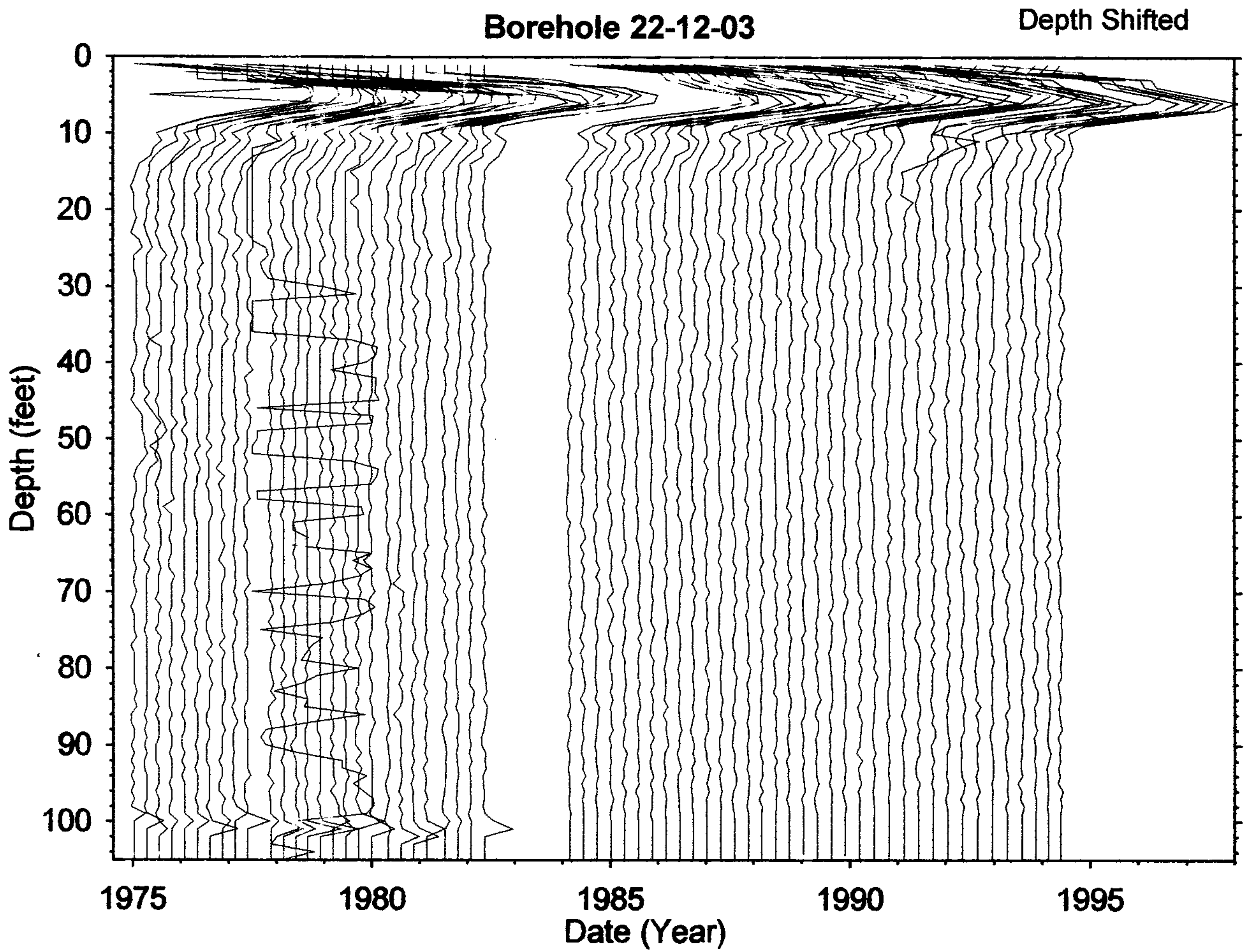
00 519

HNF-3532 -REV0



01/16/75
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
(Wide Line)
0 25000 50000
Gamma (c/s)
Borehole 22-12-03
Depth: 10-20 ft
Grade Thickness Product (feet*c/s)
0 200 400 600 800 1000
Cs-137 Decay Line
1975 1980 1985 1990 1995
Date (Year)
Average Background (c/s)
0 10 20 30 40 50
Frequency Clean (%)
0 20 40 60 80 100
Analysis by: Three Rivers Scientific
6/13/94
Gamma (c/s)
0 100 200
(Narrow Line)
Depth (feet)
0 10 20 30 40 50 60 70 80 90 100
(Wide Line)
0 25000 50000
Gamma (c/s)

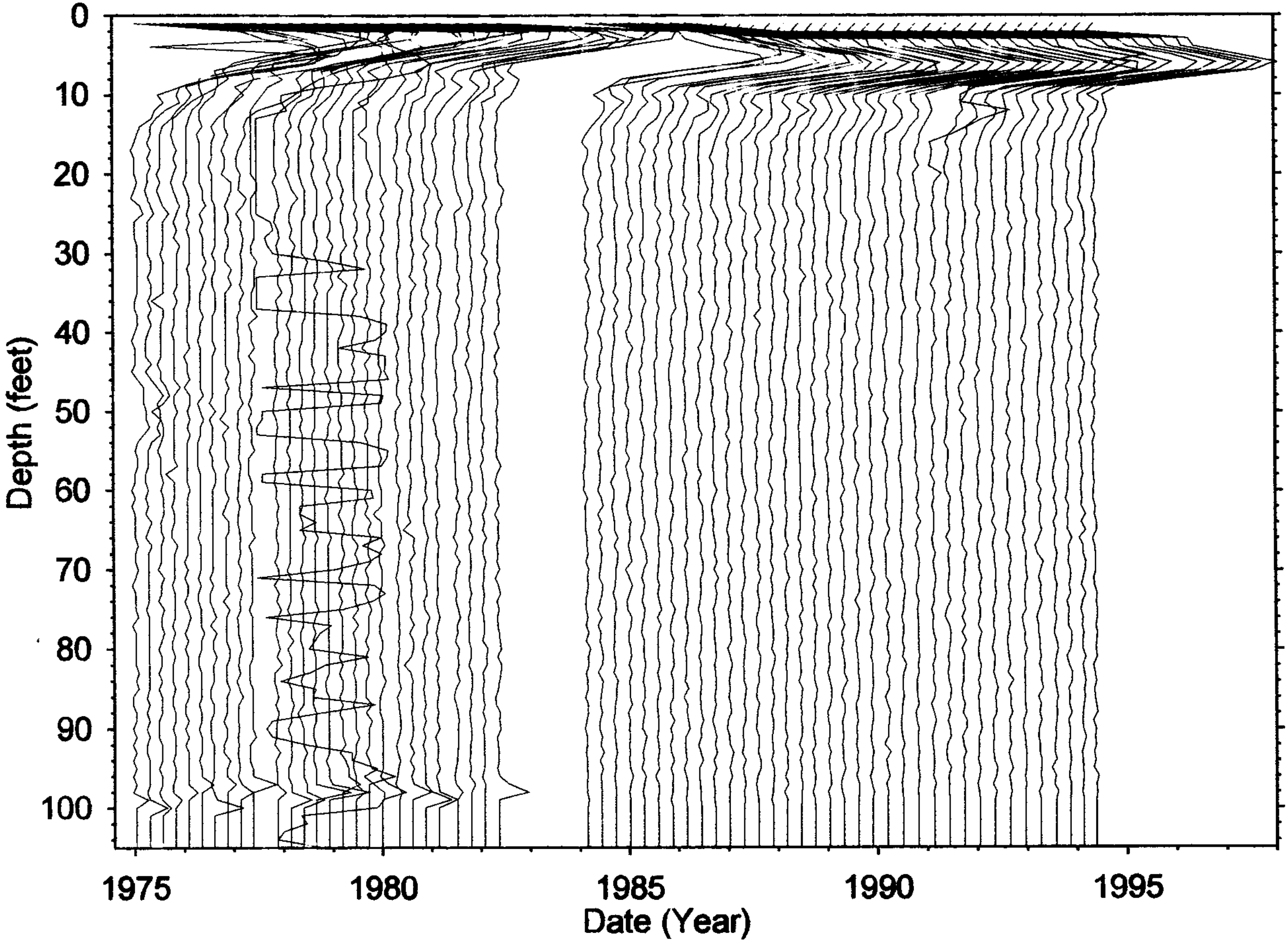
00 520



00 521

HNF-3532 -REV0

Borehole 22-12-03



HNF-3532 -REV0

Borehole 22-12-05

Contamination (Cs-137) from 0 to 20 feet is Tank Farm Activity

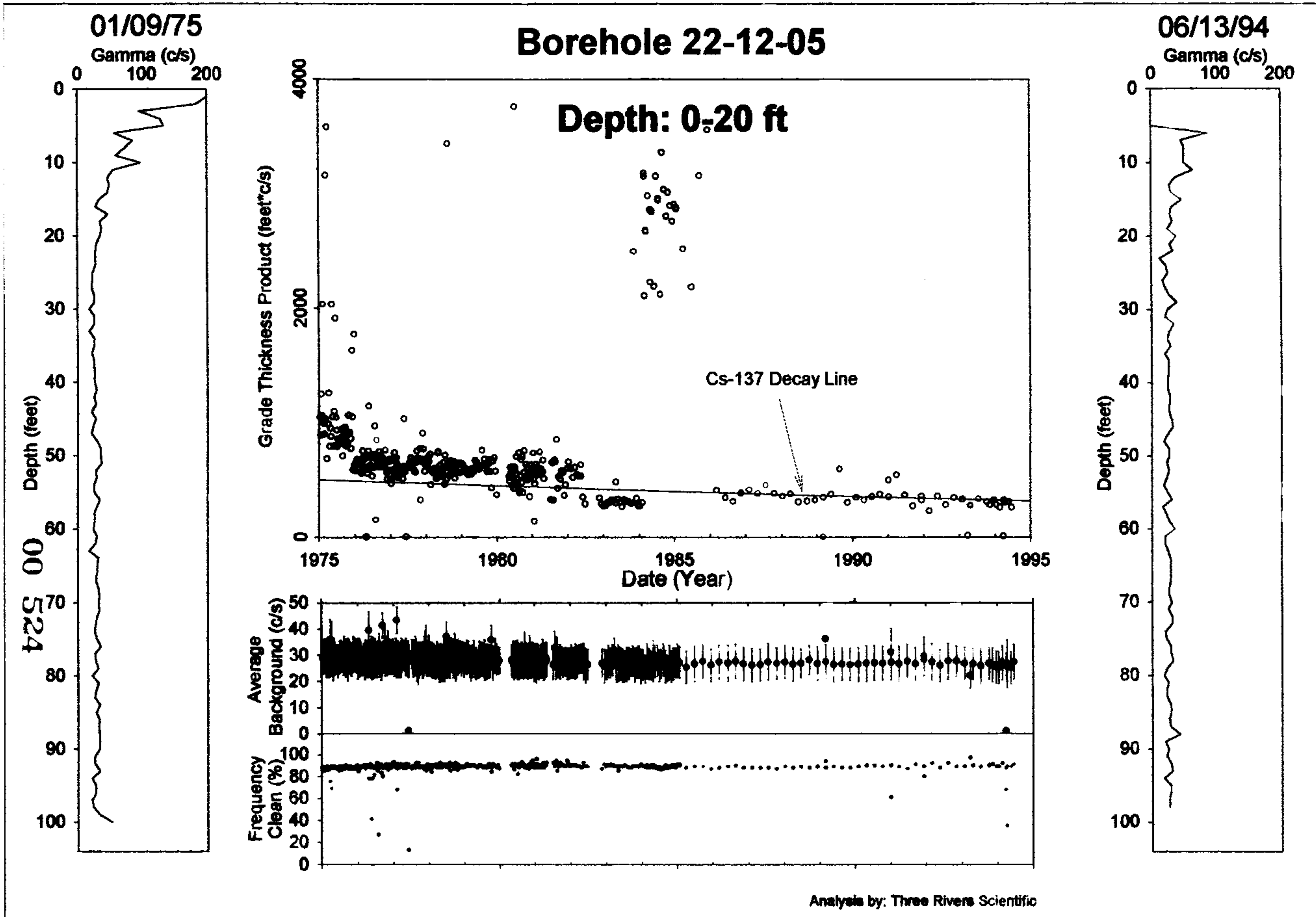
Grade Thickness Product from 0 to 20 feet is erratic from 1975 through 1986 primarily from logging procedure changes and is categorized as Tank Farm activity. Grade Thickness Product from 1986 through 1994 is decreasing within counting statistics at a rate consistent with Cs-137 (identified from HPGe detector).

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (4 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	6/13/1994
Number Surveys :	426

Analysis Notes

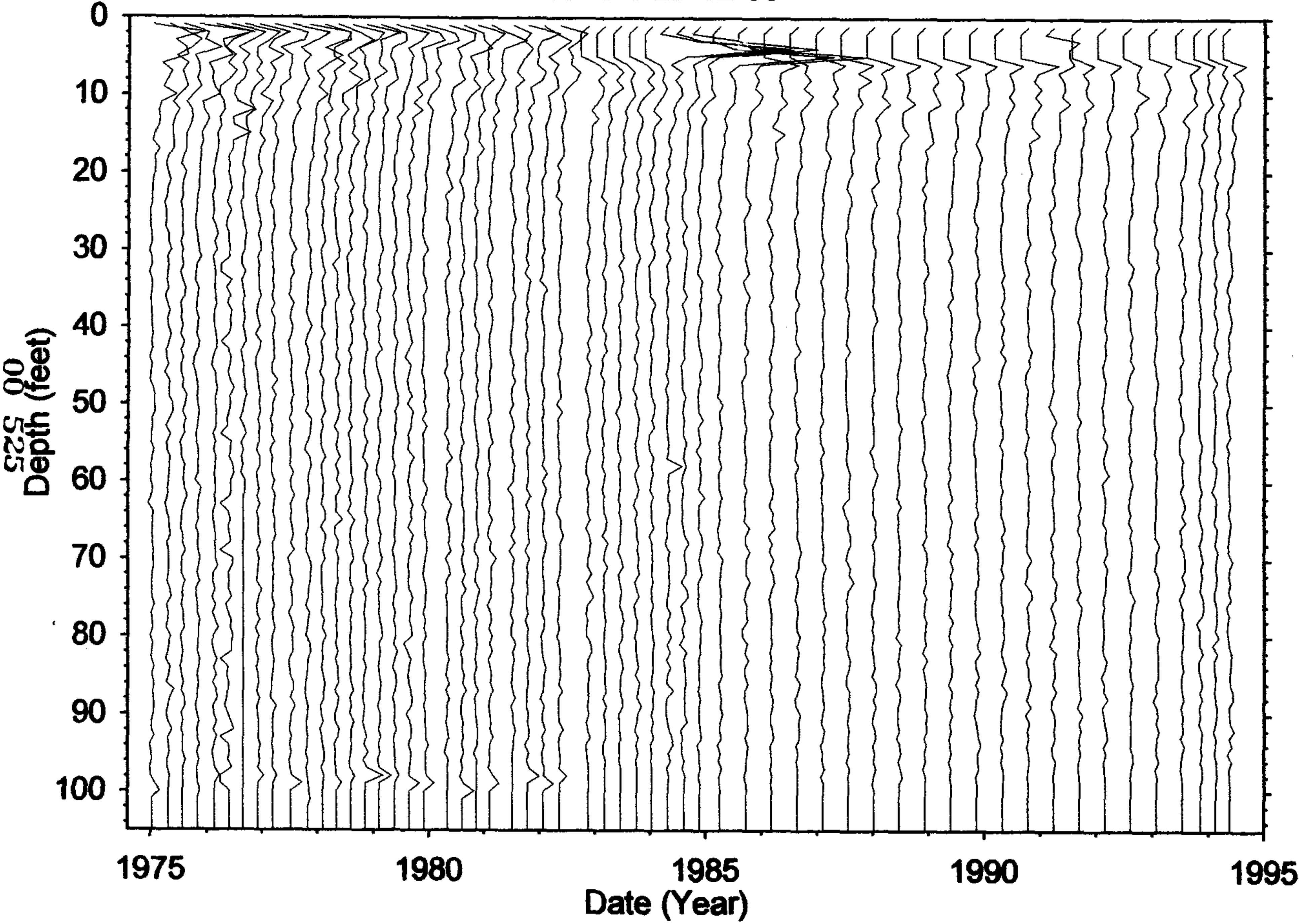
Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	25 to 40 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	**0-20 feet is TF Activity**
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



00 524

HNF-3532 - REV 0

Borehole 22-12-05



HNF-3532 -REV0

Borehole 22-12-06

Contamination (Cs-137) from 0 to 20 feet is Tank Farm Activity

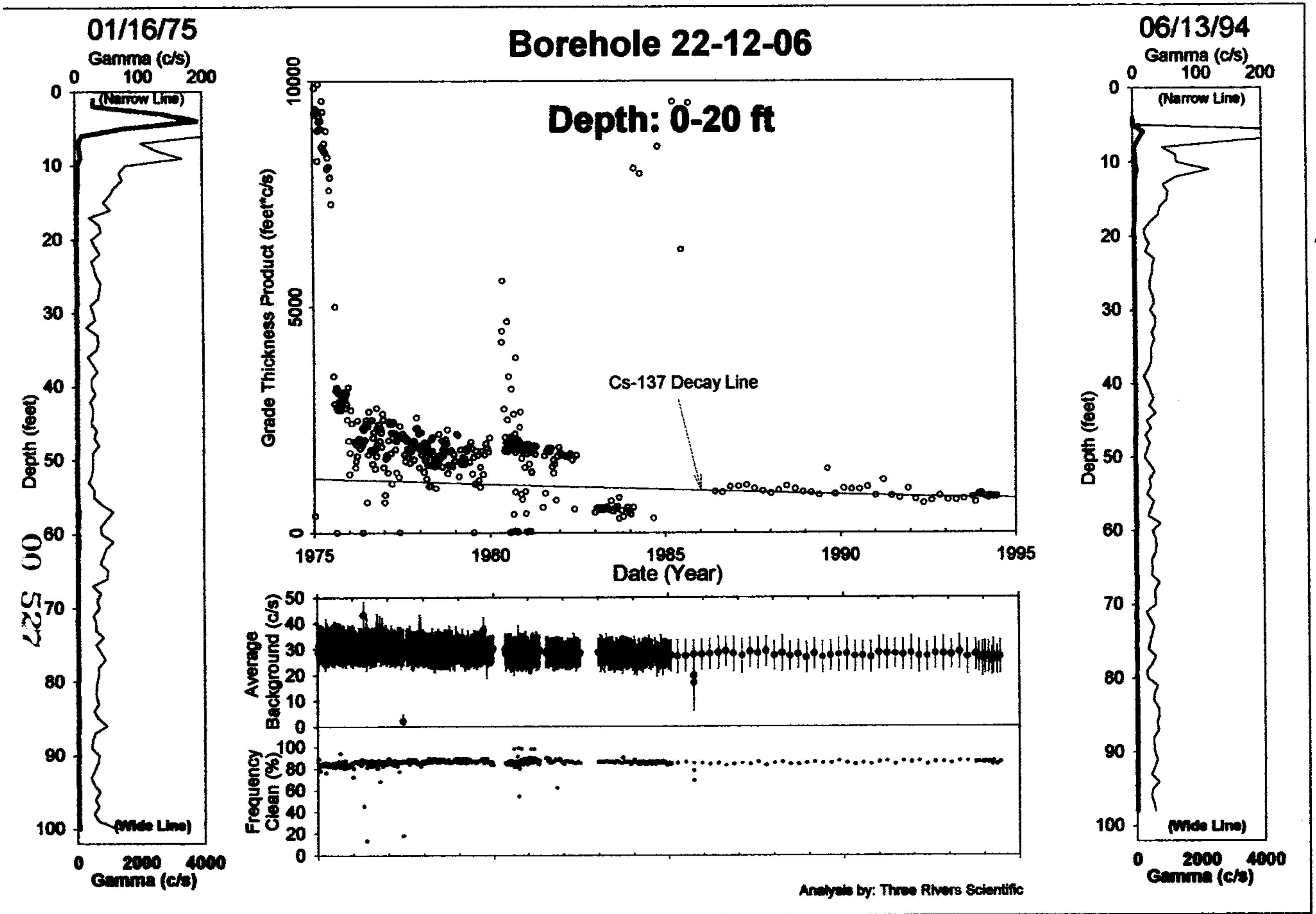
Grade Thickness Product from 0 to 20 feet is erratic from 1975 through 1986 primarily from logging procedure changes and is categorized as Tank Farm activity. Grade Thickness Product from 1986 through 1994 is decreasing within counting statistics at a rate consistent with Cs-137 (identified from HPGe detector).

Gross Gamma Survey Information

Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (4 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	6/13/1994
Number Surveys :	428

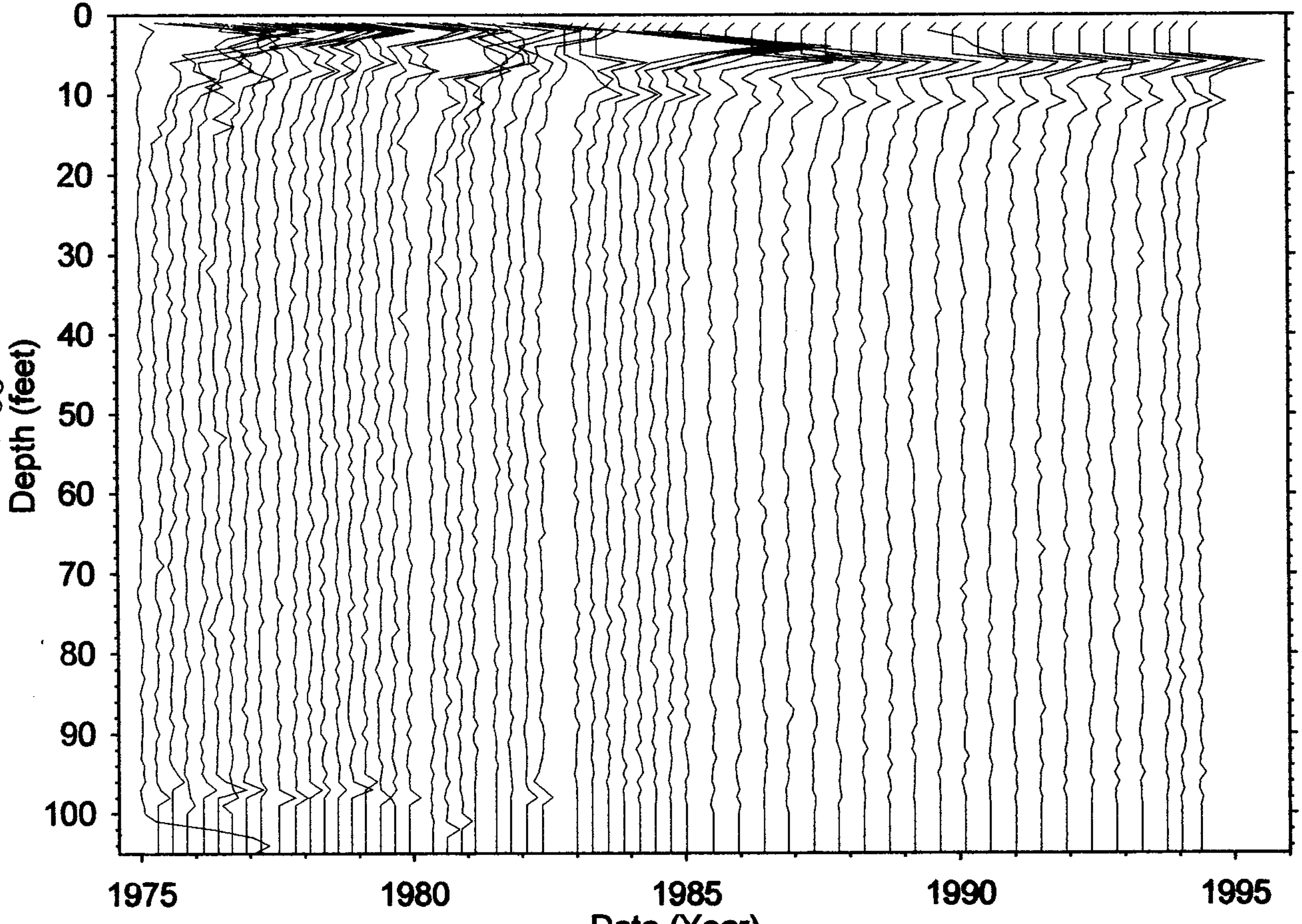
Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	20 to 40 feet
Depth(s) where Contamination Identified in Gross Gamma Surveys :	**0-20 feet is TF Activity**
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



HNF-3532 -REV0

Borehole 22-12-06



HNF-3532 -REV0

00 528

Borehole 22-12-07

Contamination (Cs-137) from 0 to 10 feet is Tank Farm Activity

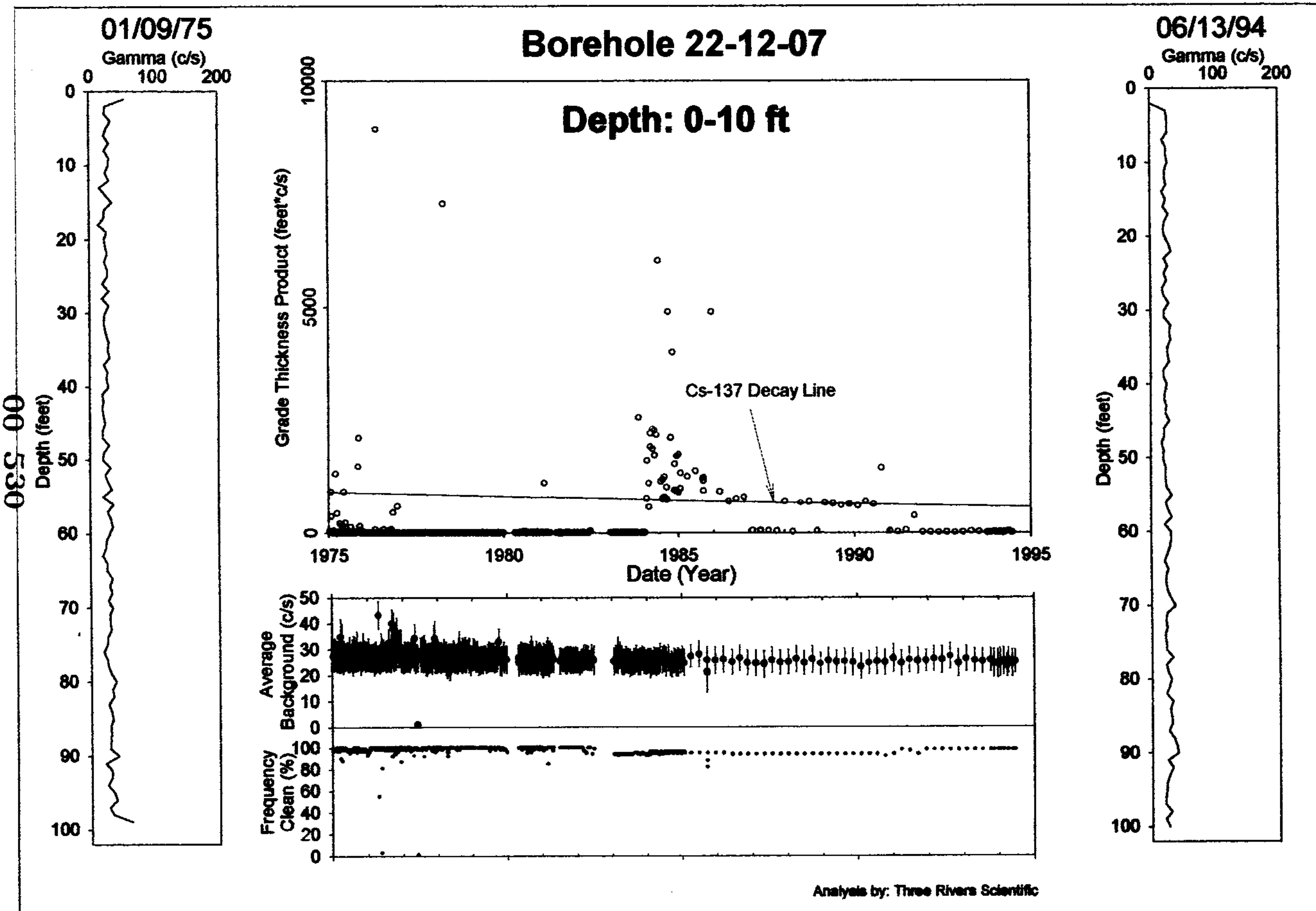
Grade Thickness Product from 0 to 10 feet is erratic throughout the monitoring interval and is categorized as Tank Farm activity. Grade Thickness Product shows that on occasion the gamma log response exceeded the background activity. A decay line for Cs-137 (identified from HPGe detector) is presented for the surveys from 1986 to 1991 that were above background.

Gross Gamma Survey Information

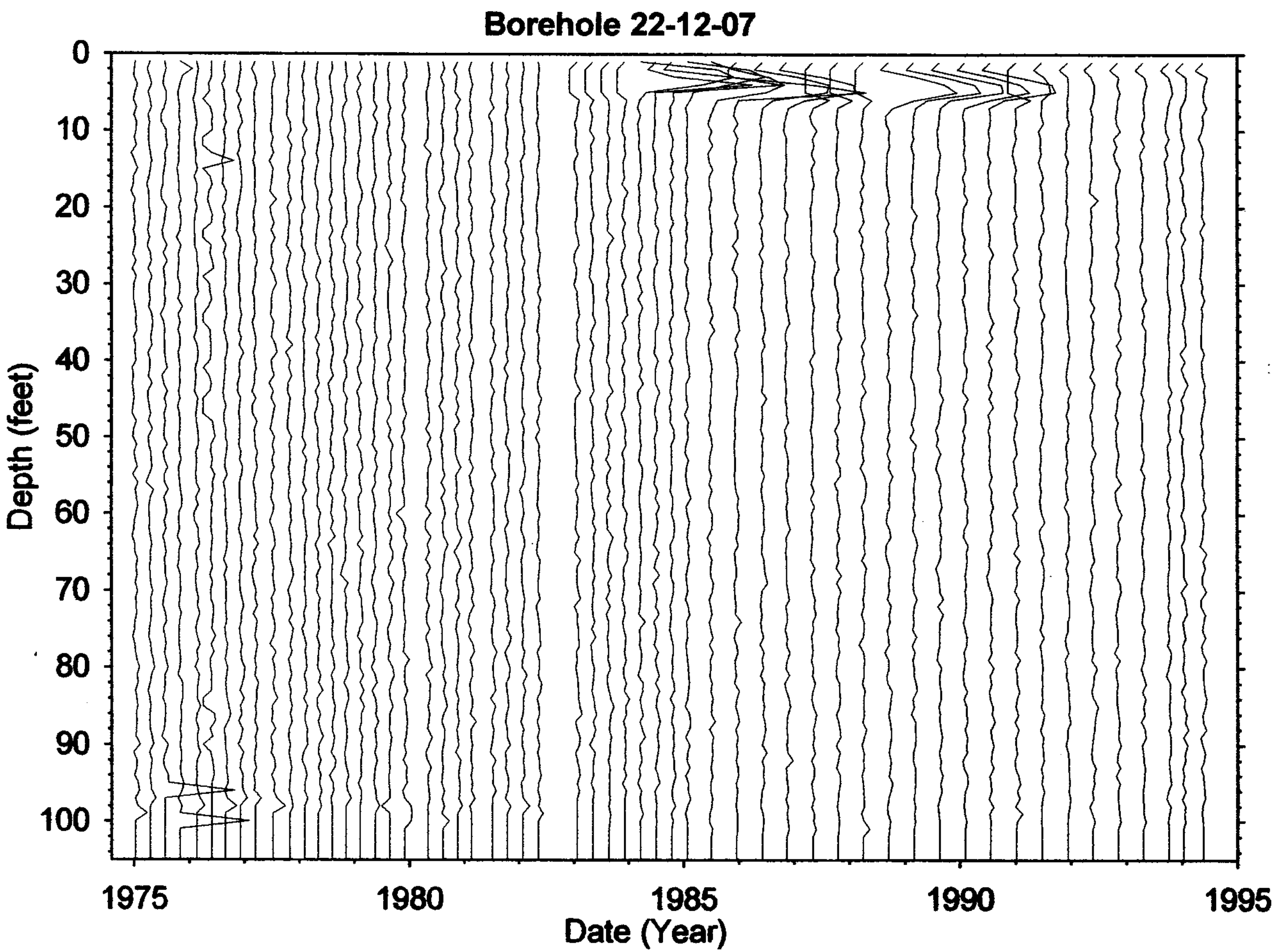
Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (2 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/09/1975
Last Survey Date :	6/13/1994
Number Surveys :	418

Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	Threshold (0< val < 50)
Depth(s) where Contamination Identified in Gross Gamma Surveys :	**0-10 feet is TF Activity**
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific



HNF-3532 -REV0


Borehole 22-12-07
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
1975
1980
1985
1990
1995
Date (Year)

Borehole 22-12-09

No Gamma-Ray Emitting Contamination was identified

No significant levels of gamma-ray contamination is present above the survey probe detection threshold between 1975 and 1995 in the vadose zone from 2 to 100 feet.

Gross Gamma Survey Information

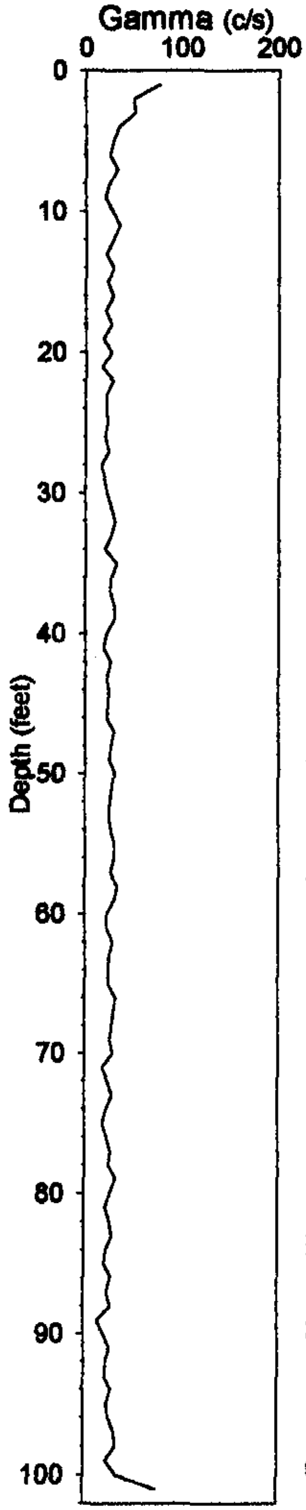
Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (4 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/16/1975
Last Survey Date :	6/13/1994
Number Surveys :	429

Analysis Notes

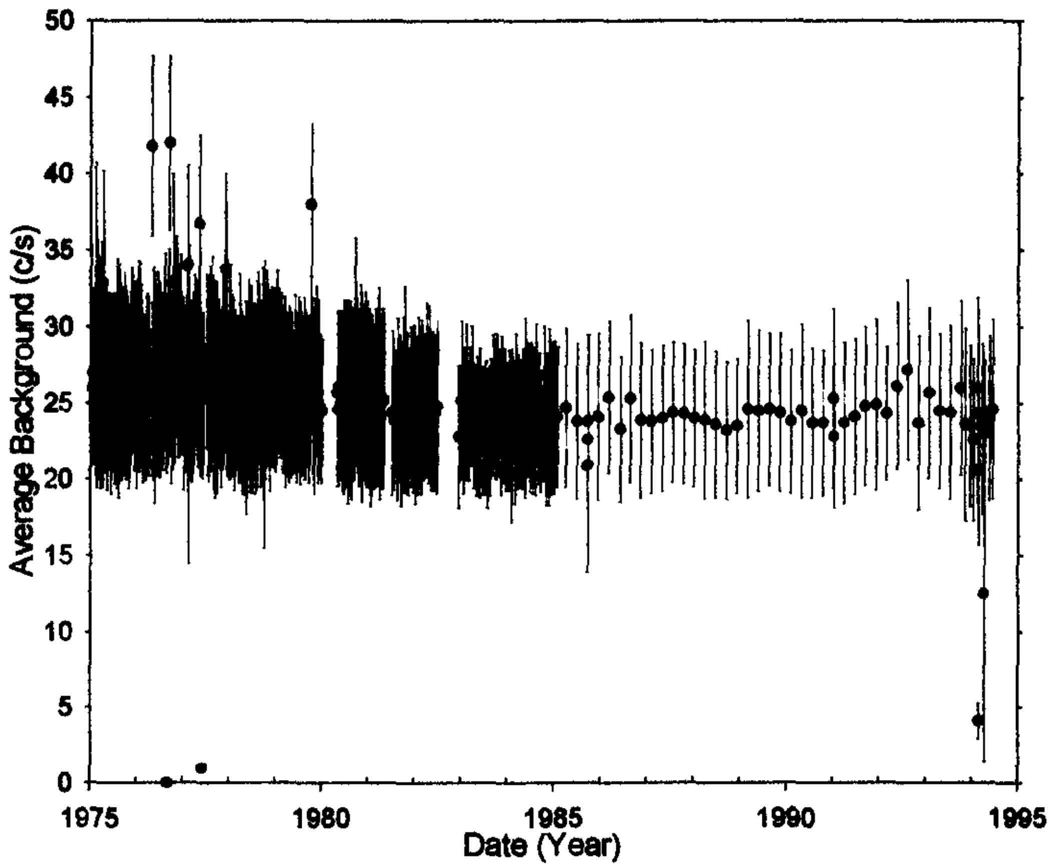
Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	Threshold (0< val < 50)
Depth(s) where Contamination Identified in Gross Gamma Surveys :	**No Contamination**
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific

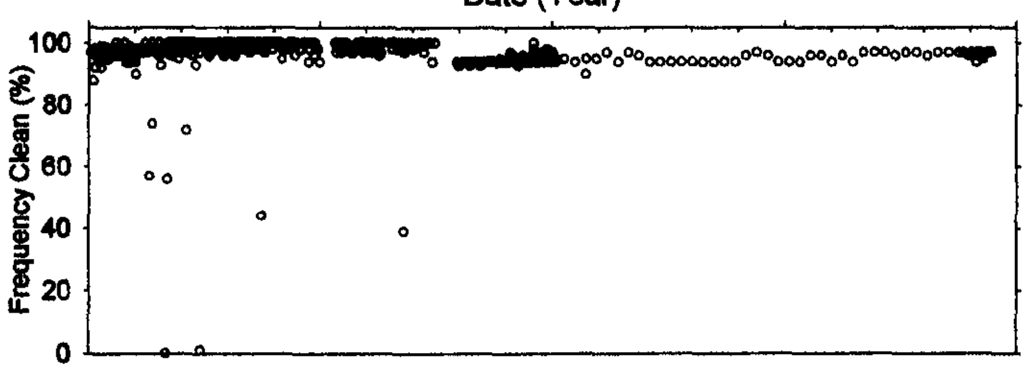
Borehole 22-12-09

Oldest Survey
1/16/1975

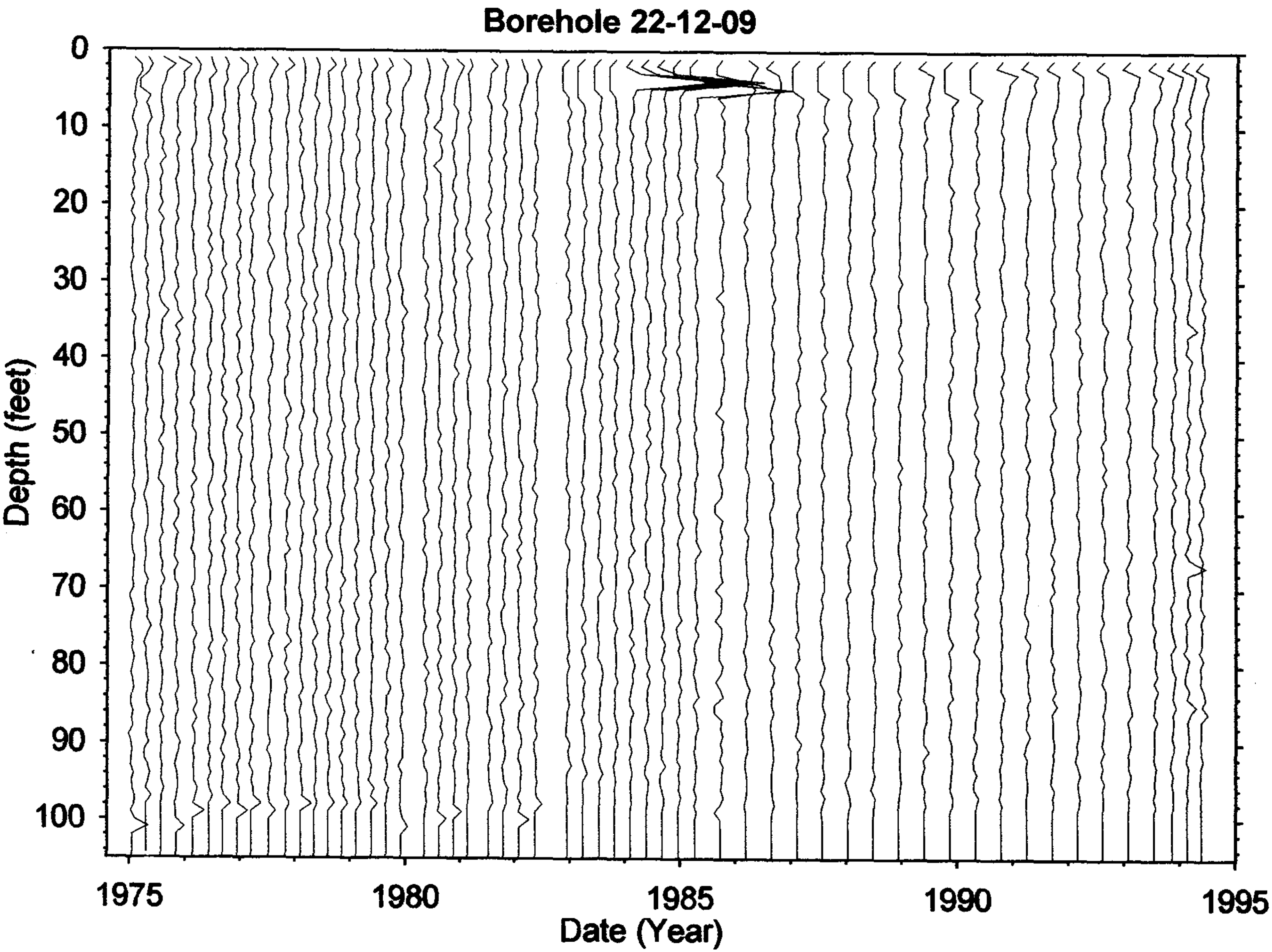


No Gamma-Ray Emitting Contamination Above Survey Detection Threshold





Analysis by: Three Rivers Scientific



HNF-3532 -REV0

Borehole 22-12-10

No Gamma-Ray Emitting Contamination was identified

No significant levels of gamma-ray contamination is present above the survey probe detection threshold between 1975 and 1995 in the vadose zone from 2 to 100 feet.

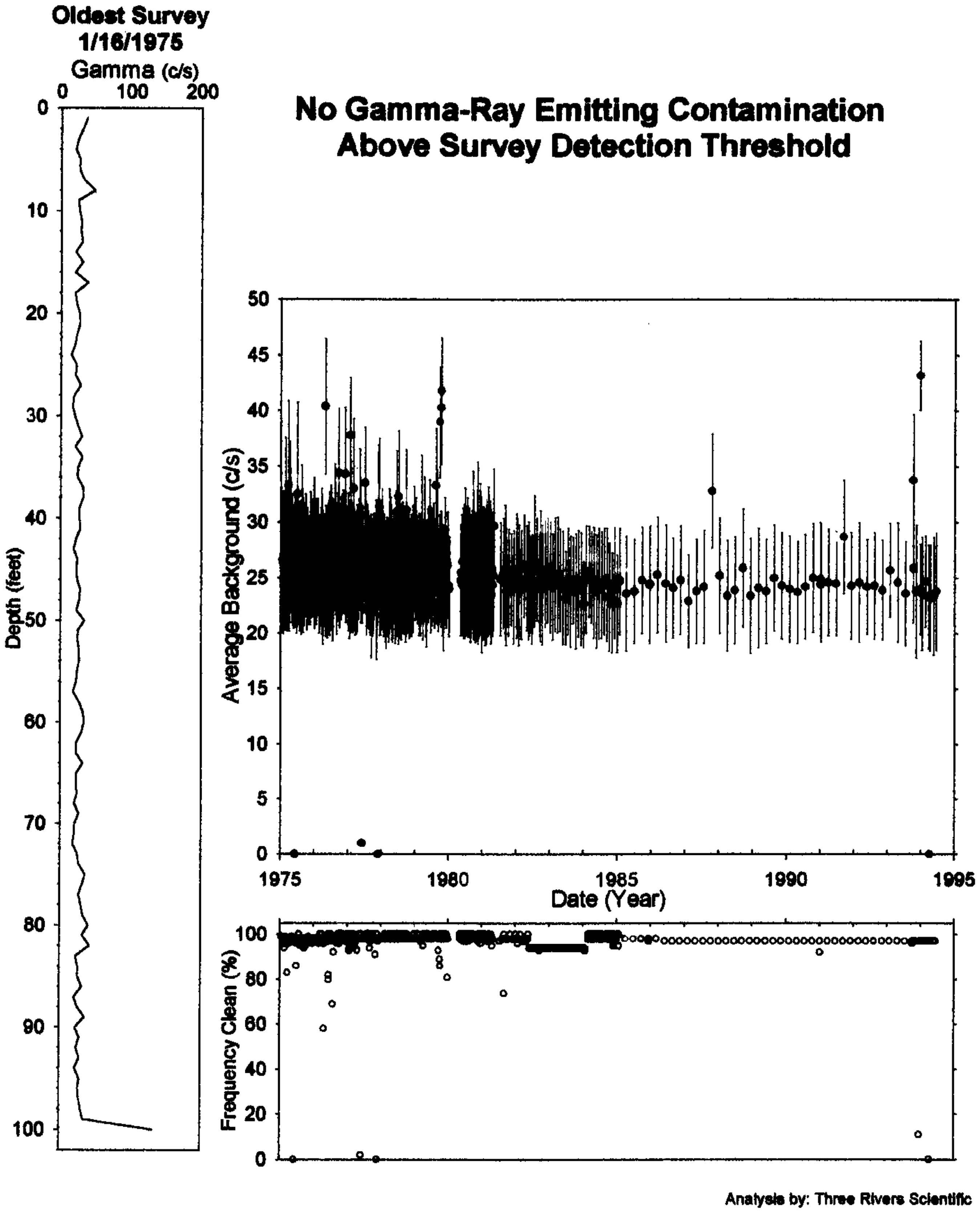
Gross Gamma Survey Information

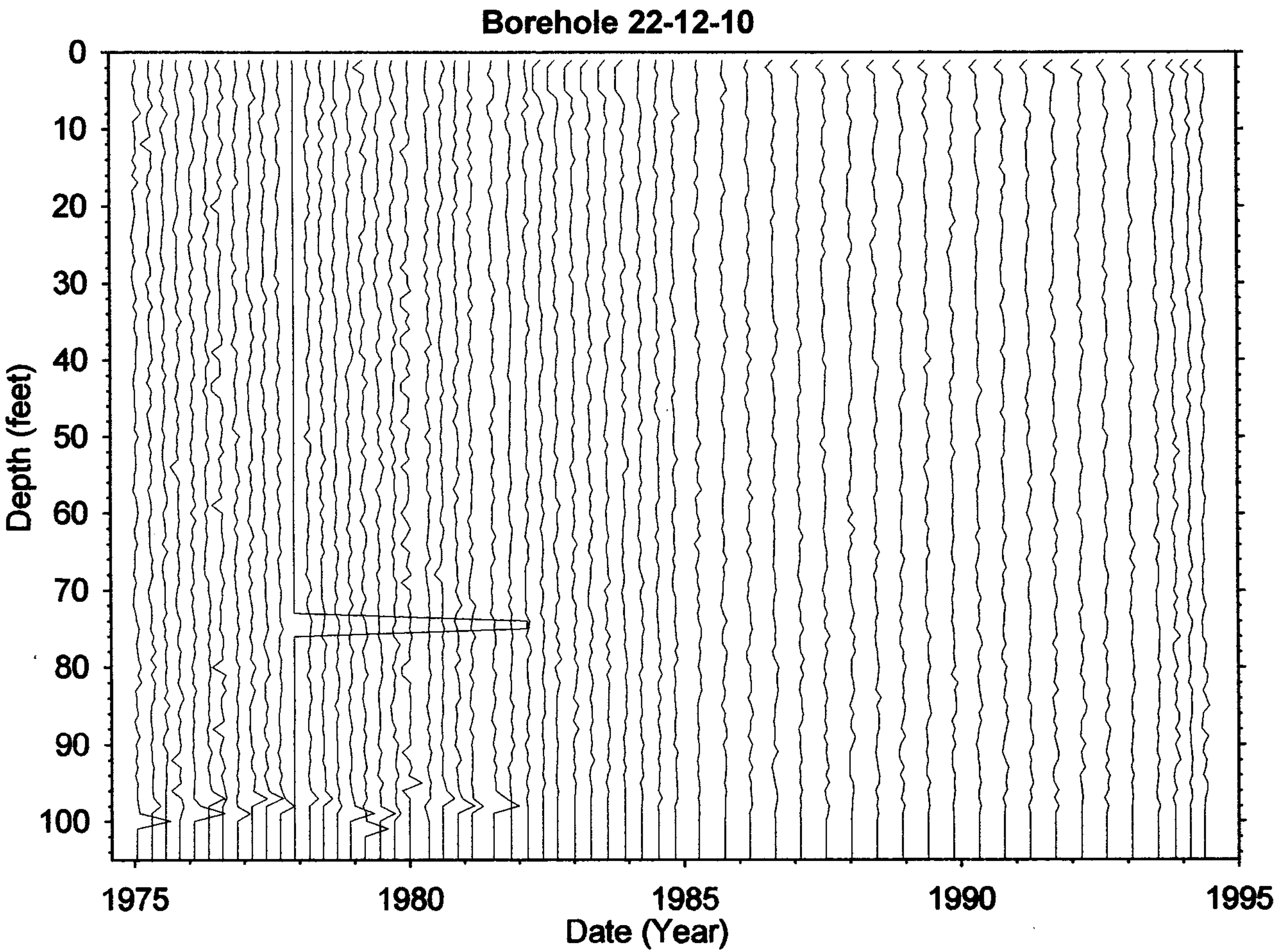
Probe Type :	04: Sodium Iodide Scintillator
Other Probe Types :	03: Neutron (4 surveys)
Borehole Depth :	100 ft
Survey Depth :	100 ft
First Survey Date :	1/16/1975
Last Survey Date :	6/13/1994
Number Surveys :	424

Analysis Notes

Number Surveys Rejected :	0
Lower Threshold for Bad Survey Values :	<= 0
Method Used to Compute Background :	Threshold (0< val < 50)
Depth(s) where Contamination Identified in Gross Gamma Surveys :	**No Contamination**
Analyst Name :	R.K. Price
Analysis By :	Three Rivers Scientific

Borehole 22-12-10





HNF-3532 -REV0

Dry Well Survey Analysis - Notes

Borehole BY(22-12-01) Total # Surveys 428 Probe Type 04
neutron surveys 3 # GR Surveys 424
Log Date: 75-01-09 1st 94-06-13 Last Presentation Plot Dates
(If different from 1st & Last)
Isotope from Spectral Survey: Cs - < 2pCi/g (0-25FT) Max Survey Depth 100
Contamination Zone Depth(s): NONE

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-07-21	23	85	
77-06-02	95	100	
79-12-27	9	98	
84-11-21	13	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
78-04-21A	SHORT SURVEY	45	
76-03-03A	SHORT SURVEY	40	
79-03-06A	SHORT SURVEY	40	
91-10-14	SHORT SURVEY	20	
83-05-03	BAD SURVEY	100	HIGH NOISE (AT BOTTOM)
91-01-03	BAD SURV	100	HIGH NOISE
93-12-17	HIGH BKG	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
76-03-03A	DEPTH	34	97%	26.8	
77-06-02	AVG BKG	98	3%	1.7	
78-04-21	DEPTH	34	50%	22.4	
79-03-06	DEPTH	33	36%	28.4	
79-10-03	AVG BKG	99	82%	41.0	
83-05-03	% CLEAN	96	52%	24.6	
91-01-03	% CLEAN	98	39%	29.1	
93-12-17	AVG BKG	98	2%	48.5	

Analysis Notes

num surveys rejected: (0) ~~YES~~ RKP NONE Background = (0<val<50)
0-25 FT (BKG = 25 - 40)
90-105 FT (BKG = 45 - 90 FT)

UPPER & LOWER ZONES HAVE EXCESSIVE VARIATION IN DATA TYPICAL OF VERY LOW ACTIVITY ZONES & POOR LOGGING PROCEDURES AT TOP & BOTTOM OF HOLE

Category: (Stable, TF Activity, Undetermined, CHANGED (CLEAN)

Analyst Name Randall Price S/W ver (TFGROSS) 2.20

Dry Well Survey Analysis - Notes

Borehole BY(22-12-03) Total # Surveys 516 Probe Type 04 14 (4 SURVEY 76,77

neutron surveys 3 # GR Surveys 509

Log Date: 75-01-10 1st 94-06-13 Last Presentation Plot Dates 75-01-16 (If different from 1st & Last)

Isotope from Spectral Survey: CS, Co, EU (CO 0-9FT & 87-98) Max Survey Depth 100

Contamination Zone Depth(s): 0-10, 40-56 ~~10-20~~ 10-20

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
77-06-02	80	100	
77-08-18	21	110	
94-04-06	91	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
76-04-01A	BAD SURVEY		
77-05-12	SHORT	50	MISSING RAD ZONE
77-06-02	BAD SURVEY	98	DEPRESSED IN RAD ZONE
77-08-18	BAD SURVEY	110	HIGH ACTIVITY (C/S) FULL ~~LOG~~ RUN
78-07-27	NO RAD ZONE	80	81-09-02 NO RAD ZONE
79-10-03	NO RAD ZONE	100	82-06-02 TRUNCATED RAD ZONE
79-11-28	LOW RAD ZONE		92-02-13 TOOL FAILURE
80-06-25	NO RAD ZONE	100	93-12-17 TOOL FAIL
80-10-16	LOW RAD ZONE	95	94-03-24 BAD RAD ZONE

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
76-12-16	HI BKG	98	86%	39.4	
77-05-05	HI BKG	97	87%	38.2	
77-06-02	% CLEAN	96	13%	69	
77-08-18	% CLEAN	106	11%	31.7	
78-06-01	AVG BKG	98	82%	43.3	
79-10-03	AVG BKG	99	42%	44.2	
92-02-13	FALSO CLEAN	98	0%	0.0	
94-03-24	AVG BKG	98	91%	35	
94-04-06	% CLEAN	94	40%	10.0	

Analysis Notes

num surveys rejected: (0) NONE Background = ~~(0<val<50)~~ 28-42FT

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Reed S/W ver (TFGROSS) V2.20

HNF-3532 -REV0

Dry Well Survey Analysis - Notes

Borehole BY(22-12-05) Total # Surveys 429 Probe Type 04

\# neutron surveys 3 # GR Surveys 426

Log Date: 75-01-09 1st 94-06-13 Last Presentation Plot Dates ______

(If different from 1st & Last)

Isotope from Spectral Survey: CS-137 < 20 pCi/g (0-20FT) Max Survey Depth 100

Contamination Zone Depth(s): 0-20FT

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-07-28	131	160	
77-06-02	84	100	
94-03-24	31	100	
94-04-06	58	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
76-05-20	B TOOL FAIL	100	
91-01-03	HIGH BKG	100	LOW IN DEPTH RANGE
80-07-02	HI C/S	105	AT SURFACE

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-04-09	AVG BKG	100	69%	35.7	
76-04-22	AVG BKG	76	78%	39.4	
76-05-20	% CLEAN	99	41%	29.7	
77-02-03	AVG BKG	98	68%	43.3	
78-06-28	AVG BKG	98	89%	37.1	
91-01-03	% CLEAN	98	61%	31.0	
94-03-24	AVG BKG	98	68%	1.1	

Analysis Notes

num surveys rejected: (0)	Background = (~~0<val<50~~) 25-40

SHARP LOW RADIATION ZONE AT SURFACE, HIGH RADAT SURFACE 84-02-23 TO 85-12-12

RADIOACTIVE ZONE ERRATIC, CATEGORIZED AS TF ACTIVITY

LOGGING OPERATION PROCEDURES CAUSED TRUNCATED SURVEYS 1983-84

HIGH ACTIVITY ZONE (84-02-23 TO 85-12-12) RECORDED WHEN SURVEYS ALLOWED FOR ADDITIONAL 2 FT TO BE RECORDED ON SURVEY

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V 2.20.

Dry Well Survey Analysis - Notes

Borehole BY (22-12-06) Total # Surveys 432 Probe Type 04
\# neutron surveys 4 # GR Surveys 428
Log Date: 75-01-09 1st 94-06-13 Last Presentation Plot Dates 75-01-76
(If different from 1st & Last)
Isotope from Spectral Survey: CS-137 <20 pCi/g (0-17FT) Max Survey Depth 100
Contamination Zone Depth(s): 0 TO 20 FT (HI VARIATION - TF ACTIVITY)

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
75-12-31	19	98	85-09-18 (A,B) 20, 100FT
77-06-02	80	100	85-09-19 (A,B) 12, 100'
80-09-18	30	80	
81-10-27	24	85	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-01-09	BAD SURVEY	170	RAD ZONE NOT AT PROPER DEPTH
75-08-21A	NO RAD ZONE	60	
76-05-20A	BAD SURVEY	100	NOISY 82-06-02 LOST RAD ZONE
77-06-02	NO RAD ZONE	100	TO 84 02-02
79-07-12	NO RAD ZONE	30	DATE LOG OPER PROC CHANGES:
80-07-30	NO PEAK		82-12-29 / 84-02-23 / 86-06-04

81-01-29 NO RAD / HIGH AT SURFACE / LOST HI CS AT 0'

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
76-04-22	AVG BKG	96	45%	43.0	
76-05-20	% CLEAN	97	13%	33.4	
76-09-04	AVG BKG	97	80%	37.3	
77-06-02	AVG BKG	98	18%	2.1	
79-09-18	AVG BKG	97	85%	37.2	
81-10-27	% CLEAN	89	62%	29.3	
85-09-19	AVG BKG	99	78%	16.7	

Analysis Notes

num surveys rejected: (0) ZERO Background = ~~(0<val<50)~~ 20-40
RADIATION ZONE 0-17FT, HIGH VARIATION: TF ACTIVITY
AND HAS LOGGING OPER PROCEDURE PROBLEMS

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V2.20

Dry Well Survey Analysis - Notes

Borehole BY C22-12-07 Total # Surveys 421 Probe Type 04
neutron surveys 2 # GR Surveys 418
Log Date: 75-01-09 1st 94-06-13 Last Presentation Plot Dates
(If different from 1st & Last)
Isotope from Spectral Survey: CS-137 0-5FT <5pCi/g Max Survey Depth 102
Contamination Zone Depth(s): 0-10FT

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-05-26	16	98	
77-06-02	96	100	
85-09-19	13	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
76-05-20B	TOOL FAIL	100	
76-04-22	HI BKG	100	
HI ACTIVITY AT SURFACE (VARIABLE) 84-02-01 TO 90-10-10			

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
76-04-22	AVG BKG	97	55%	43.2	
76-05-20	% CLEAN	97	3%	30.0	
76-09-09	AVG BKG	97	92%	40.0	
76-10-27	AVG BKG	100	96%	36.3	
77-06-02	% CLEAN	97	1%	1.0	

Analysis Notes

num surveys rejected: (0) ZERO Background = (0<val<50) YES
ERRATIC ACTIVITY, ASSIGN AS TF ACTIVITY

Category: (Stable, TF Activity, Undetermined, CHANGED

Analyst Name Randall Price S/W ver (TFGROSS) V2.20

Dry Well Survey Analysis - Notes

Borehole BY(22-12-09) Total # Surveys 432 Probe Type 04
neutron surveys 42 # GR Surveys 429
Log Date: 75-01-16 1st 94-06-13 Last Presentation Plot Dates
(If different from 1st & Last)
Isotope from Spectral Survey: CS-137 <10 p Ci/g 0-5 FT Max Survey Depth 100
Contamination Zone Depth(s): NO ZONES

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-09-02	59	60	
77-06-02	96	100	
78-09-27	54	100	
81-10-27	38	60	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
76-05-20A	NOISE AT BOTTOM	100	
77-02-10A	NOISY SURVEY	100	
79-03-06	HI CPS AT 60FT	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-02-07	LENGTH	202	88%	31.9	
76-04-22	AVG BKG	99	57%	41.8	
76-09-02	LENGTH	60	0%	0.0	
76-09-09	AVG BKG	98	56%	42.0	
77-06-02	% CLEAN	97	1%	1.0	
78-09-27	% CLEAN	98	44%	24.9	
79-02-21	AVG BKG	98	97%	4.1	
94-04-06	AVG BKG	98	95%	12.5	

Analysis Notes

num surveys rejected: (0) NONE Background = (0<val<50) OK

Category: (Stable, TF Activity, Undetermined, CHANGED CLEAN

Analyst Name Randall Price S/W ver (TFGROSS) 2.20.

HNF-3532 -REV0

Dry Well Survey Analysis - Notes

Borehole B4(22-12-10) Total # Surveys 428 Probe Type 04
neutron surveys 4 # GR Surveys 424
Log Date: 75-01-16 1st 94-06-13 Last Presentation Plot Dates ____
(If different from 1st & Last)
Isotope from Spectral Survey: CS-137 <2 pCi/g 0-10 FT Max Survey Depth 100
Contamination Zone Depth(s): ____

GAPS.Txt

Survey Date	num. Gaps	approx #Sampl's	Comment
76-07-28	18	20	
77-06-02	94	100	
77-11-23	85	80	
79-12-21	17	95	
81-09-02	14	50	
94-04-06	99	100	

HI-ZONES.Txt

Survey Date	Reason Selected	approx #Samp's	Comment
75-06-05	HI BKG	100	
76-0640AB	TOOL NOISE	100	
93-12-17	HI NOISE	100	

BackGnd.Txt

Survey Date	Reason Selected	num. Samples	Feq. Clean	Avg. Bkg	Comment
75-06-05	AVG BKG	98	0%	0.0	
76-04-22	AVG BKG	97	58%	40.4	
77-01-20	AVG BKG	95	93%	37.8	
77-06-02	AVG BKG	96	2%	1.0	
77-11-23	% CLEAN	87	0%	0.0	
77-09-18	79-10-03	98	89%	40.3	
93-12-17	AVG BKG	95	11%	43.2	
94-04-06	% CLEAN	75	0%	0.0	

Analysis Notes

num surveys rejected: (0) ZERO Background = (0<val<50)
NO RADIATION ZONE PRESENT (75-95)

Category: (Stable, TF Activity, Undetermined, CHANGED CLEAN)

Analyst Name Randall Price S/W ver (TFGROSS) V2.20.

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